SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1950 Literature Review—Research Committee

Tampa Sewage Works—Langdon

Paper Mill Color Reduction—Churchill

MAY, 1951—VOL. 23, No. 5

Make Plans to Attend

TWENTY-FOURTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

CENTRAL STATES SEWAGE WORKS ASSOCIATION

MUNICIPAL AUDITORIUM

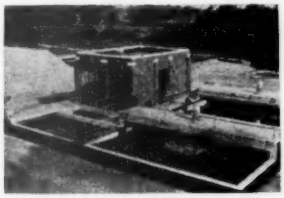
ST. PAUL, MINN.

October 8-11, 1951

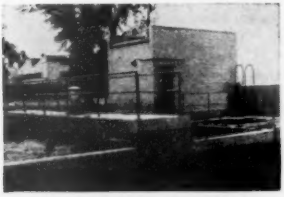
FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

Specify CHICAGO "PAKAGE" PLANTS



• FOR SMALL COMMUNITIES
Spring Hill, La.



• FOR INDUSTRIAL PLANTS
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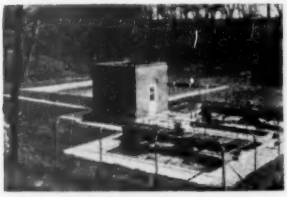

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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In other words, how will the chlorinator stand up under continuous use?

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This instrument is one which may be recommended without hesitation whenever accuracy and long range of measurement are required.

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SIMPLEX
VALVE AND METER COMPANY

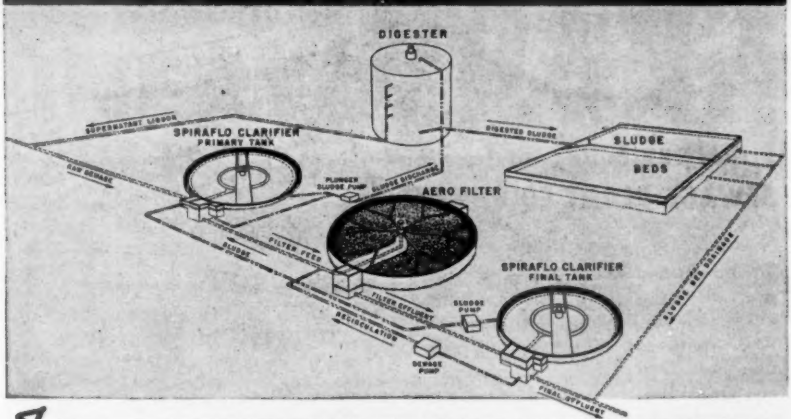
MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Michigan Sewage and Industrial Wastes Association	Hotel Pantlind, Grand Rapids, Mich.	June 4–6, 1951
New York Sewage and Industrial Wastes Association and New England Sewage Works Association	Springfield, Mass.	June 7–8, 1951
Alabama Water and Sewage Association	University of Ala., Tuscaloosa, Ala.	June 15, 1951
Institute of Sewage Purification	Buxton, England	June 18–22, 1951
Ohio Sewage and Industrial Wastes Treatment Conference	Neil House, Columbus, Ohio	June 20–21, 1951
Canadian Institute on Sewage and Sanitation	Royal York Hotel, Toronto, Ont.	Aug. 20–22, 1951
Pennsylvania Sewage and Industrial Wastes Association	State College, Pa.	Aug. 22–24, 1951
Iowa Sewage Works Association	Hotel Tall Corn, Marshalltown, Iowa	Sept. 11–13, 1951
Kentucky–Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 19–21, 1951
South Dakota Water and Sewage Works Conference	Charles Gurney Hotel, Yankton, S. Dak.	Sept. 19–21, 1951
Rocky Mountain Sewage Works Association	Cosmopolitan Hotel, Denver, Colo.	Sept. 26, 1951
North Dakota Water and Sewage Works Conference	Gardner Hotel, Fargo, N. Dak.	Sept. 26–28, 1951
Missouri Water and Sewerage Conference	Robidoux Hotel, St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
West Virginia Sewage and Industrial Wastes Association	Daniel Boone Hotel, Charleston, W. Va.	Oct. 3–4, 1951

Federation of Sewage and Industrial Wastes Associations
Municipal Auditorium, St. Paul, Minn.
October 8–11, 1951

Florida Sewage and Industrial Wastes Association	The Princess Issena Hotel, Daytona Beach, Fla.	Oct. 28–31, 1951
New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951

There's a YEOMANS Plant FOR EVERY WASTE TREATMENT NEED!



THIS LOW RATE, HIGH CAPACITY TRICKLING FILTER PLANT IS ESTABLISHING AMAZING RECORDS FOR HIGH PURIFICATION AT EXCEPTIONALLY LOW COST

These figures show a typical result produced by a Yeomans installation of the "Aero-Filter" and "Spiraflo" Clarifier in combination.

Overall plant efficiency is always higher when these units are used together. The method is especially effective for treating strong industrial wastes.

OPERATIONAL DATA . . . SPIRAFLO—AERO-FILTER PLANT *

1949 Date	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids PPM	Per Cent Reduction	Per Cent PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	255	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2566	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant furnished on request, as well as operating data from other installations.

"Spiraflo" Advantages

- Increased B.O.D. and settleable solids removal —influent is introduced tangentially into annular race around the periphery. Sewage spirals downward slowly and enters main clarification compartment at the bottom of the tank. Uniform, slow diffusion of waste under the skirt results in greatly reduced velocities and provides maximum removal of settleable solids.
- Greater removal of finely divided particles—due to upward flow through sludge blanket. This increases flocculation and results in more effective removal of finely divided particles before waste enters the effluent weirs.
- Straight-wall design minimizes construction costs.

"Aero-Filter" Advantages

- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary
- Operating cost is lowest of any type of complete sewage treatment
- Uninterrupted and almost complete momentary bed coverage minimizes troubles from odors, freezing, ponding, filter flies
- All returns made direct to the filter—no oversize primary tank required.

FOR INDUSTRIAL WASTES, TOO . . . Many types of industrial wastes can be successfully treated by direct application to the Aero-Filter without preliminary sedimentation.

Bulletins containing full details and helpful engineering data will be sent promptly upon request

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☐ "Spiraflo" Clarifier—No. 6790
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Business.....
Address.....
City.....State.....

What better PROOF that REX builds outstanding SEWAGE PLANT EQUIPMENT

A sewage plant installs REX Sewage Treatment Equipment one year, orders more the next, still more the next. Fifteen years later this plant is still ordering REX equipment. We think you'll agree that here is positive proof that REX equipment is giving more than just average service.

And this is not an isolated example. In plant after plant, REX is giving such outstanding service that when more equipment is needed, REX is automatically the first choice. At right is a list of REX installations made at the Nine Springs Sewage Treatment Plant, Madison, Wisconsin, over the last 16 years:

H. O. Lord, Chief Engineer, Madison Metropolitan Sewerage Commission.
Greeley and Hanson, Consulting Engineers, Chicago, Illinois.

1934-35

Sludge Collectors for 2 primary tanks, each 31' x 85' x 10'
TOW-BRO Sludge Removers for 2 round final tanks, each 70' in diameter and 14' 6" deep.
Chain and Bucket Type Grit Collectors and Grit Washer for 2 grit chambers, each 7½' x 35' x 6'

1936

2 Mechanically Cleaned Bar Screens for channels 5' x 20' and 5' x 13'

1938

Sludge Collectors for 2 primary tanks, each 33' x 120' x 10'
TOW-BRO Sludge Remover for a sludge thickener tank 30' in diameter and 10' deep.
TOW-BRO Sludge Remover for a final settling tank 85' in diameter and 13' deep.

1949

Grit Collector for channel 5½' x 50' x 6'
Sludge Collectors and Scum Collecting Pipes for a primary tank 31' x 101' x 10'
TOW-BRO Sludge Remover for final settling tank 85' in diameter and 12½' deep.
3 Mechanically Cleaned Bar Screens for channels 5'x19'

Rex Conveyor Sludge Collectors at the Madison plant.

Rex TOW-BRO Sludge Remover installed at the Madison plant.

For complete information on any item of REX Sewage Treatment Equipment, send for your copy of Bulletin 48-41.

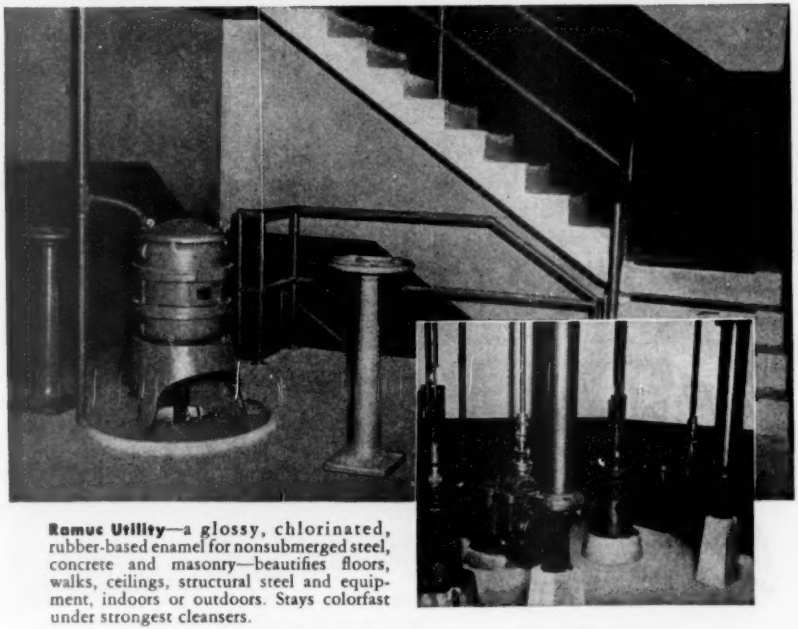
CHAIN BELT REX COMPANY — SEWAGE TREATMENT EQUIPMENT . . . .

CHAIN BELT COMPANY, 1606 W. Bruce St., Milwaukee 4, Wis.

Atlanta Engineers
Wiedeman and Singleton *Specify*

INERTOL PAINTS

throughout Fulton County Sewage Plants



Ramuc Utility—a glossy, chlorinated, rubber-based enamel for nonsubmerged steel, concrete and masonry—beautifies floors, walks, ceilings, structural steel and equipment, indoors or outdoors. Stays colorfast under strongest cleansers.

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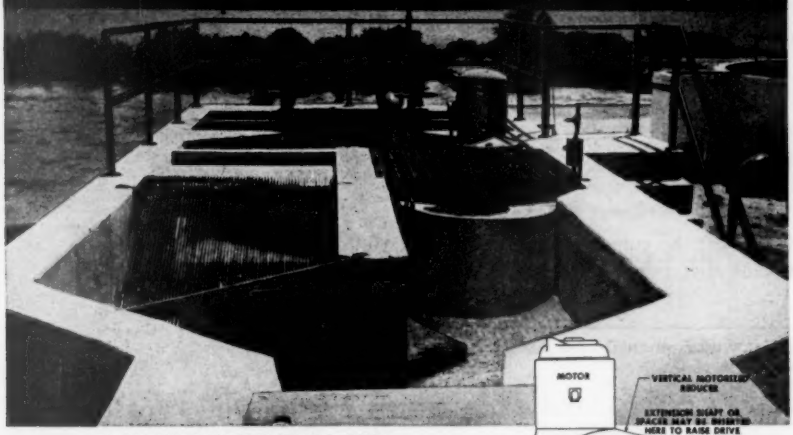
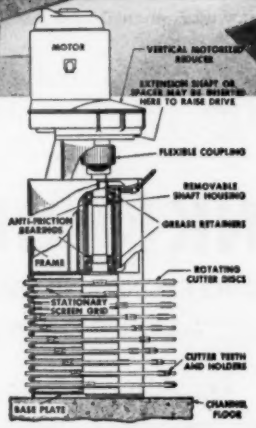
GRIDUCTOR

STRAIGHT CHANNEL SEWAGE SCREENING AND CUTTING



GRIDUCTOR INSTALLATION (Size 36), DAYTONA BEACH, FLORIDA



Combines Coarse and Fine Screening Actions with Cutting and Shearing

HERE'S a *better* way to reduce the size of solids! GRIDUCTOR does it by intermittent cutting and shearing without excessively increasing the dissolved organic content of the sewage. Easily and quickly installed in new or existing sewage screen channels. Protects treatment plant units from fouling and clogging. Delivers more readily settleable solids to primary clarifier, and larger quantity of sludge to digester increasing gas production. Get all the facts about this sturdy, efficient equipment. Send for Bulletin No. 5100. Write today . . or, ask our nearest field engineer for complete information.

INFILCO

• BETTER WATER CONDITIONING • AND WASTE TREATMENT SINCE 1894

INFILCO INC.

TUCSON, ARIZONA

WITH OFFICES IN PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

Looking for efficient, LOW-COST SCREENINGS REMOVAL?

Immediate, overwhelming acceptance proves new LINK-BELT Thru-Clean Bar Screen the answer for handling screenings from sewage and industrial wastes

YES, 36 new Thru-Clean Bar Screens were sold in the 12 months following Link-Belt's initial announcement! Take a look at the partial list of installations and the consulting sanitary engineers who were responsible for them.

Then look at the advanced engineering illustrated by the photos below. They suggest how this new Link-Belt development can solve the problem of removing screenings from sewage or industrial wastes in your plant.

You can get the complete story by calling your nearest Link-Belt office. Or write for Folder No. 2327.

A FEW USERS OF THRU-CLEAN BAR SCREENS

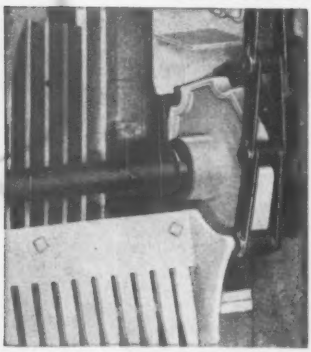
Location	*Sanitary Engineer*
Nassau County, N. Y.	Greeley & Hansen
Union Grove, Wis.	W. G. Hirchoffer
Port Huron, Mich.	Drury, McNamee & Porter
Idabel, Okla.	Collins Engineering
Storm Lake, Iowa	Buell & Winters
Camden, N. J.	Havens & Emerson
Rochester, Minn.	Toltz, King & Day

LINK-BELT

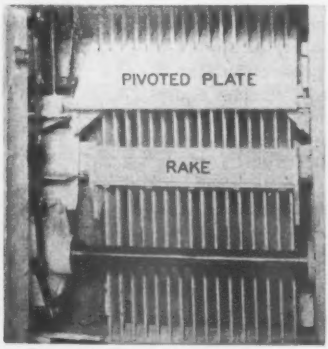
SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices in principle cities. 12,310-A

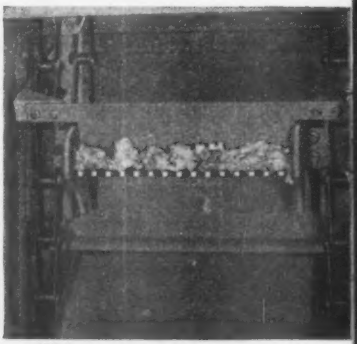
How rakes automatically clean bars "from the back"



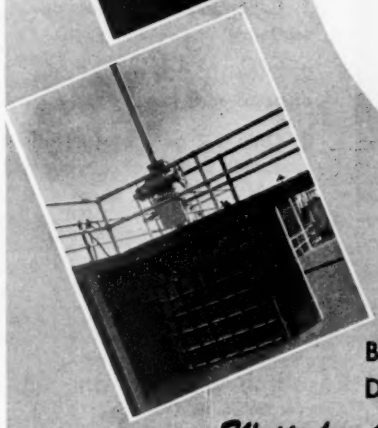
Segmented steel rake is about to start its low-friction vertical movement. Entering from downstream side (*shown*), its forward and upward force precludes jamming or clogging. Travel starts at lowest point of channel, catches all solids retained by screen.



Cold-rolled steel bars, uniformly spaced, form screen. They are rigidly fixed at bottom of channel, extend only 6 in. beyond pivoted plate immediately above high water level. Simple, rugged construction minimizes maintenance. Low speed cuts power consumption.



Hinged wiper blade thoroughly cleans rake fingers, deposits screenings in trough for removal to shredder, disposal can or incinerator. Note the heavy, long-pitch Link-Belt chains, selected for trouble-free long life and assurance of proper travel for rakes.



Pekrul Gates

PEKRUL MODEL 56 GATES with Philadelphia Limitorque Model M30 Motorized Lifts in operation at Denver Sewage Disposal Plant.

PEKRUL GATES are engineered to meet the most rigid requirements for:

Flood Control
Levees
Irrigation
Water Works
Dams
Sewage Disposal
Reservoirs
Pumping Plants
Oil Refineries
Fish Hatcheries
Rearing Ponds
Recreation Pools
Cooling Towers

PEKRUL GATE DIVISION

MORSE
BROS. MACHINERY CO.
DENVER, COLORADO

Write for Catalog 49

What Does Sludge Incineration Cost?

Year	Tons Incinerated		Total Cost Operation & Maintenance	
	Dry Solids	Wet Cake	Per Ton Dry Solids	Per Ton Wet Cake*
1940	37,091	116,000	$1.36	$.436
1941	35,993	112,000	1.23	.394
1942	33,838	106,000	1.17	.375
1943	32,955	103,000	1.39	.445
1944	33,758	105,500	1.27	.407
1945	32,428	101,000	1.38	.442
1946	33,581	105,000	1.54	.493
1947	36,633	114,000	1.42	.455
1948	34,549	108,000	1.79	.573
1949	34,787	108,500	1.73	.554
Average	34,56.13	107,900	$1.43	$.457

*Based on average of 68% moisture in filter cake

The figures above were taken from Annual Reports of Minneapolis-St. Paul Sanitary District, 1940-1949. Nichols Multiple Hearth Mechanically Rabbled Furnaces are employed.

Nichols Multiple Hearth Incineration Shows Low Ten Year Average Cost.

1. Dependable LOW Cost operation.
2. Over 100,000 tons of cake disposal each year.
3. Only 0.2 gals. of fuel oil consumed per ton of cake produced.
4. Individual furnace units operated continuously throughout the year without shutdowns for repairs.

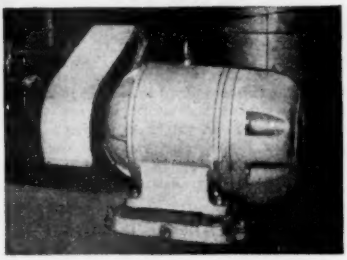
Nichols Engineering & Research Corporation
70 Pine Street • New York 5, N. Y.
Pacific Coast Office: 40 So. Los Robles Avenue, Pasadena 1, Calif.
Mid-Western Office: 1920 N. Meridan Street, Indianapolis 2, Ind.
Canadian Office: 1477 Sherbrooke Street West, Montreal 25

EARLY PLANNING PAYS OFF

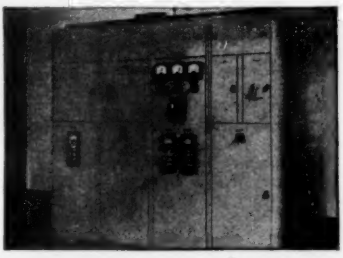
General Electric offers latest electrical ideas to city officials, consultants, machinery manufacturers

A modern sewage disposal plant requires the complete co-ordination of electrical, mechanical and architectural features by a sewage disposal specialist: the consulting engineer. To the consulting engineer, his clients, and the machinery builder, General Electric offers years of experience in the application of electric equipment to sewage treatment.

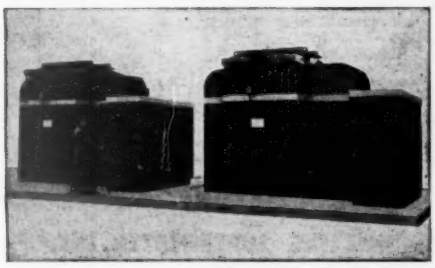
Call on G-E application and design engineers early in the planning stage. They will expertly select and integrate components to form a completely co-ordinated electrical system . . . the heart of every modern sewage treatment plant. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*



MOTOR reliability is always of primary importance. G-E application engineers select motors with correct operating characteristics and structural features for each particular application.



CONTROL, like the Cabinetrol* unit pictured above, is tailored to your specifications. Cabinetrol is factory-assembled for complete co-ordination of control components.



UNIT SUBSTATIONS combine transformers and switchgear in one package. Both G-E load-center (under 600 volts output), and master unit substations, shown here, (over 600) provide reliable power distribution.

*Reg. Trade-mark of General Electric Company

GENERAL ELECTRIC

666-61

the only proven means of Sewage Sludge Disposal which combines incineration and drying

As will be seen by the list at the lower right, there have been seven major installations of C-E Raymond Systems in the last five years which combine the two usual disposal methods . . . drying and incineration. The C-E Raymond System usually provides for high temperature deodorizing employing preheater equipment to save fuel and assure low stack temperatures.

C-E Raymond System installations are in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

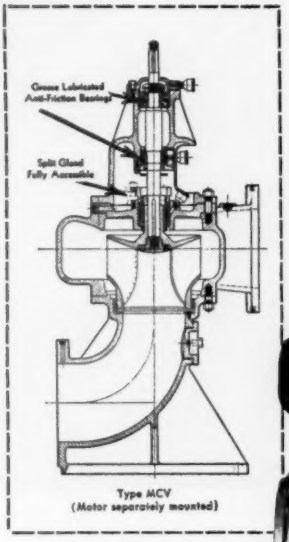
A major reason for the success and widespread acceptance of C-E Raymond Systems is the exceptional background of experience represented in their design and manufacture. The Raymond Division has long been a recognized leader in the fields of grinding and drying, and Combustion Engineering—Superheater, Inc. has enjoyed similar standing in the combustion and heat recovery fields. The services of C-E specialists are available to assist you in finding the best solution to your sludge disposal problem.

Industrial sludges a problem?
C-E Raymond Flash Drying and Incineration Systems have been the answer for others. Write for information. B-464

Representative list of C-E Raymond installations since 1945	Incineration	Drying	High Temperature Deodorizing
BALTIMORE, Md.		X	
BETHLEHEM, Pa.	X	X	
CHICAGO, Ill. (W. Southwest)	X	X	
FOND DU LAC, Wis.		X	X
HOUSTON, Texas		X	
LOS ANGELES, Calif.	X	X	X
SAN DIEGO, Calif. (Extension)		X	X
SAN FRANCISCO, Calif.		X	X
SCHENECTADY, N. Y.	X	X	X
SHEBOYGAN, Wis.		X	X
WATERBURY, Conn.	X	X	X
COLNE VALLEY, England	X	X	X
RECIFE, Brazil		X	
WASHINGTON, D. C.	X	X	

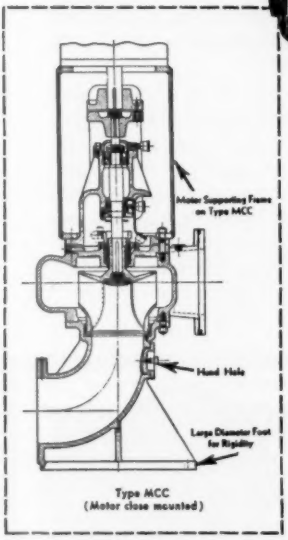
COMBUSTION ENGINEERING—SUPERHEATER, INC.
FLASH DRYER DIVISION
1315 North Branch Street Chicago 22, Illinois
Western Office: San Fernando Bldg., Los Angeles 13 • Eastern Office: 200 Madison Ave., N.Y. 16

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT



Type MCV
(Motor separately mounted)

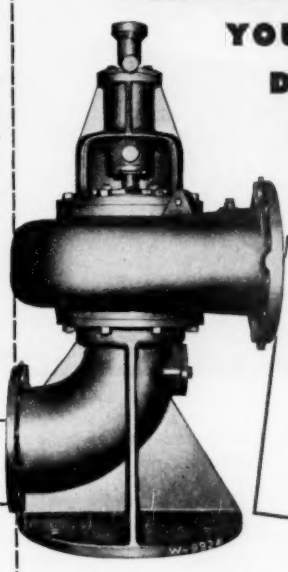
Mixflo, Type MCV
with base elbow suction nozzle



Type MCC
(Motor close mounted)

There's a Mixflo Pump

THAT WILL MEET YOUR SEWAGE DISPOSAL NEEDS— *Exactly!*



Worthington Offers The Largest Selection Of Sizes And Types In A Single Line

Non-clogging two-vane closed impellers, grease-lubricated anti-friction bearings, easy accessibility to the split stuffing-box gland and impeller eye . . . are typical of the many Worthington Mixflo features assuring low-cost, trouble-free sewage pumping.

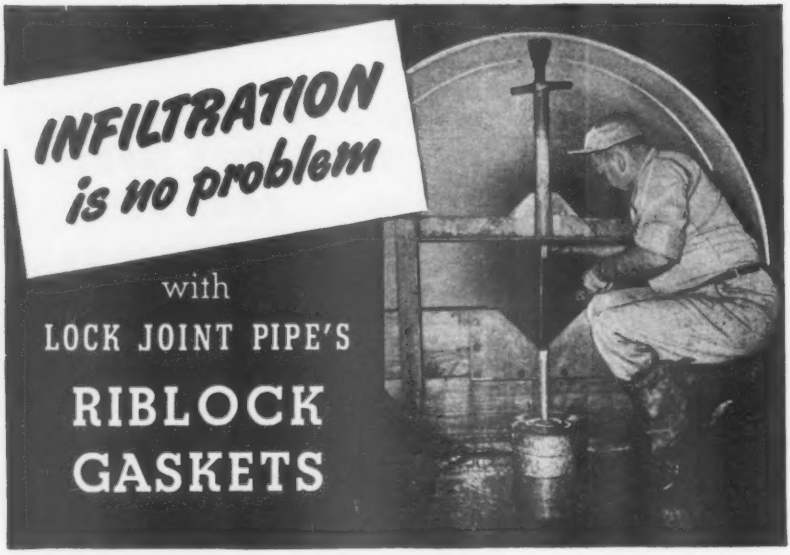
No Need To Guess!

And along with performance-proved excellence in every mechanical and hydraulic detail, the Mixflo line offers you the widest choice of sizes and types in the field. So there's no need to compromise on a pump that's "about" right — you're sure to find a Mixflo that's *exactly right* for your particular requirements.

Bulletin W-317-B16 describes the various Mixflo types made in 10", 12" and 16" sizes. Worthington also builds Mixflos in sizes up to 84", with open or closed impellers and for horizontal or vertical drives. For more Mixflo facts that prove *there's more worth in Worthington*, contact our nearest District Office. Or write to *Worthington Pump and Machinery Corporation, Harrison, N. J.*

WORTHINGTON

W0.1



Actual field tests made on pipe laid under severe ground water conditions prove that the problem of infiltration can be overcome by using Lock Joint Reinforced Concrete Sewer Pipe equipped with Riblock Gaskets.

Bogert-Childs Associates, consulting engineers for the enormous Overpeck Sewer Project, conducted a detailed weir test on approximately 7,000 feet of 60" Lock Joint Reinforced Concrete Sewer Pipe with Riblock joints which were installed across the North Jersey swamps and marshlands. This test, which showed only 15 per cent of the volume of infiltration permitted in the specifications, pointed conclusively to the value of Lock Joint sewer pipe and Riblock gaskets for installations of this difficult nature.

For nearly 50 years Lock Joint Pipe Company has been furnishing the most durable and dependable sewer, storm drain, and culvert pipe obtainable. Now, by including Riblock Gaskets in the specifications, you can also assure joints with permanently reliable protection against ground water infiltration.

• • • • •

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, New Jersey

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. Denver, Col. • Kansas City, Mo. • Valley Park, Mo. Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. M. Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis.

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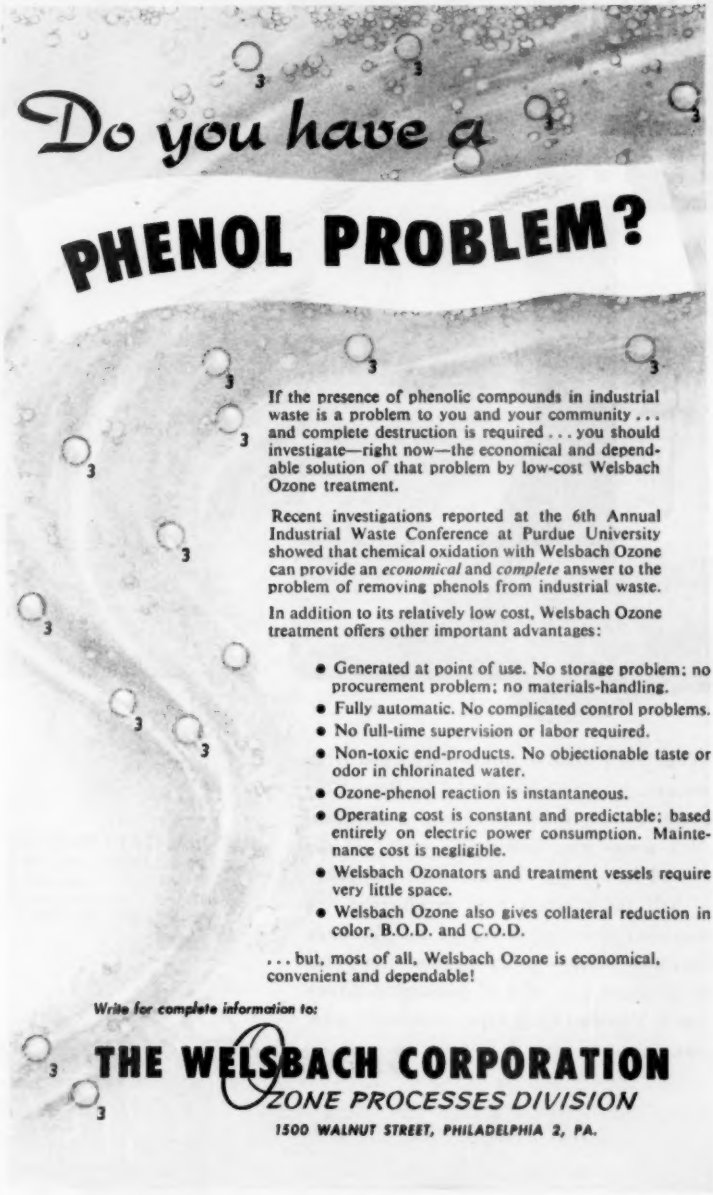
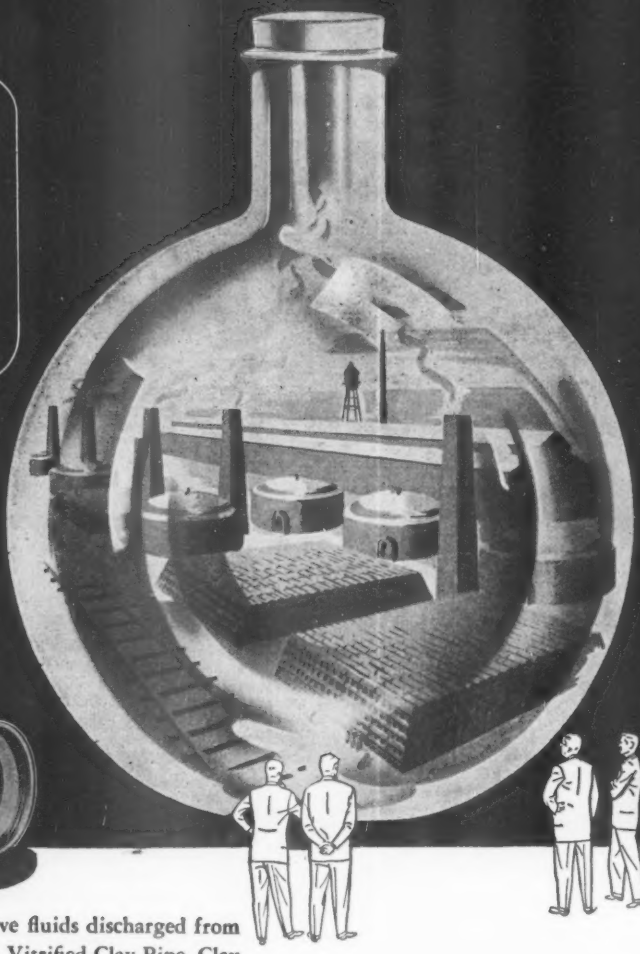

Do you have a
PHENOL PROBLEM?
If the presence of phenolic compounds in industrial waste is a problem to you and your community . . . and complete destruction is required . . . you should investigate—right now—the economical and dependable solution of that problem by low-cost Welsbach Ozone treatment.
Recent investigations reported at the 6th Annual Industrial Waste Conference at Purdue University showed that chemical oxidation with Welsbach Ozone can provide an economical and complete answer to the problem of removing phenols from industrial waste.
In addition to its relatively low cost, Welsbach Ozone treatment offers other important advantages:
• Generated at point of use. No storage problem; no procurement problem; no materials-handling.
• Fully automatic. No complicated control problems.
• No full-time supervision or labor required.
• Non-toxic end-products. No objectionable taste or odor in chlorinated water.
• Ozone-phenol reaction is instantaneous.
• Operating cost is constant and predictable; based entirely on electric power consumption. Maintenance cost is negligible.
• Welsbach Ozonators and treatment vessels require very little space.
• Welsbach Ozone also gives collateral reduction in color, B.O.D. and C.O.D.
. . . but, most of all, Welsbach Ozone is economical, convenient and dependable!
Write for complete information to:
THE WELSBACH CORPORATION
OZONE PROCESSES DIVISION
1500 WALNUT STREET, PHILADELPHIA 2, PA.

corrosives can't harm CLAY PIPE



The industrial acids and corrosive fluids discharged from modern factories have no effect on Vitrified Clay Pipe. Clay is completely immune to any form of corrosive chemical activity, whether it's sewer gas, industrial waste, or the destructive acids found in sewage. Today, with chemistry involved in nearly half the nation's total production, it's more important than ever to install sewerage and drainage lines that are chemically inert — proof against the acids and soil conditions of today . . . and of tomorrow. *Every* city of *every* size needs Vitrified Clay Pipe — the *only* pipe that never wears out.

NATIONAL CLAY PIPE MANUFACTURERS, INC.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio

SPECIFY *Vitrified* **CLAY PIPE**

CLAY PIPE NEVER WEARS OUT!

WRITE FOR DETAILED INFORMATION

Additional information and data on Vitrified Clay Pipe, Wall Coping and Clay Flue Lining sent FREE on request. State your specific questions. Simply contact the regional office nearest you.

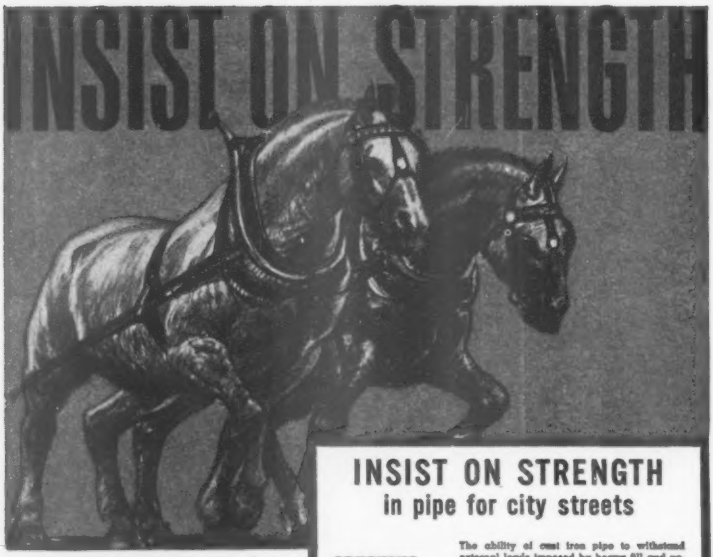
C-151-10

Protect your sewage plant Investment with "Varec" SAFETY INSURANCE

. . . "VAREC" sewage gas control equipment is safety insurance that you pay for only once! It represents only 1/10 of 1% of your entire sewage treatment plant investment, yet "VAREC" provides lifelong protection against the possibility of fire and explosion.
DIGESTER PROTECTION — "VAREC" Figure No. 5800C Pressure Relief and Vacuum Breaker Valve with Flame Arrester.
GAS HOLDER PROTECTION — "VAREC" Figure No. 280A Pressure and Vacuum Relief Valve.
BOILER PROTECTION — "VAREC" Figure No. 187 Pressure Regulator and "VAREC" Figure No. 450 Flame Trap Assembly.
SYSTEM PROTECTION — "VAREC" Figure No. 440 Pressure Relief and Flame Trap Assembly.
PIPING PROTECTION — "VAREC" Figure No. 70 Explosion Relief Valve.
LABORATORY GAS LINE PROTECTION — "VAREC" Figure No. 52A Flame Check.
PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY
COMPTON, CALIFORNIA, U. S. A.

S-11 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*



Long life and low maintenance cost of mains laid under city streets depend not only on effective resistance to corrosion but on definite strength factors. The four strength factors that pipe must have to withstand beam stress, external loads, traffic shocks and severe working pressures, are listed in the box opposite. No pipe that is deficient in any of these strength factors should ever be laid in paved streets of cities, towns or villages. Cast iron water and gas mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe not only resists corrosion but combines all the strength factors of long life with ample margins of safety.

INSIST ON STRENGTH
in pipe for city streets

CRUSHING STRENGTH — The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH — When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 13,920 lbs.

SHOCK STRENGTH — The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 6 times on the same spot from progressively increased heights of 6 inches.

BURSTING STRENGTH — In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

CAST IRON PIPE RESEARCH ASSOCIATION, THOS. F. WOLFE, MANAGING DIRECTOR, 122 SO. MICHIGAN AVE., CHICAGO 3.

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 **MAY, 1951** **Number 5**

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Kathleen E. Fox and Emilyanne Hamilton, *Editorial Assistants*

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REPAIR COSTS ON DORR TYPE S (ROUND) CLARIFIERS

SIZE	100'-200' DIA.	UNDER 100' DIA.
PURCHASE PERIOD	1931-42	1932-35
YEARS IN SERVICE	4-15	11-14
NUMBER OF UNITS	115	95
TOTAL REPAIR COSTS	$3,568	$2,933
PER UNIT	$31	$31
TOTAL REPAIR COST FOR ENTIRE PERIOD AS % OF ORIGINAL COST	0.27	.77

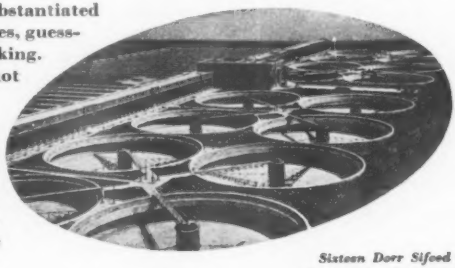
✓ *Check these facts . . .*

ON DORR CLARIFIER MAINTENANCE COSTS!

A glance at the figures above will tell you exactly what repair costs can be expected with Dorr Clarifiers.

These figures are substantiated facts . . . not estimates, guesswork or wishful thinking. We believe they cannot be matched.

Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?



Sixteen Dorr Sifeed Clarifiers at Easterly Treatment Plant, Cleveland, Ohio, installed in 1932.

We'd like to tell you how Dorr Clarifiers stack up on performance too. Ask a Dorr engineer for the facts.

DORRCO

DORR

WORLD-WIDE RESEARCH · ENGINEERING · EQUIPMENT

THE DORR COMPANY · ENGINEERS · STAMFORD, CONN.
Associated Companies and Representatives in the principal cities of the world

1950 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1950 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

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In the review for 1949 (This Journal, **22**, 5, 593; May, 1950), attention was called to the rapidly expanding literature on sewage, industrial waste, and water pollution. Last year's review covered 398 references, whereas this year the numbers have swollen to 661. The two main reasons for the increase in references are a considerably larger number of articles published and more extensive coverage. Despite the very large increase in references, the individual reviewers have made a special effort to condense the review as much as possible.

The occurrence and survival of pathogenic organisms in sewage and sludge has received renewed interest in connection with the utilization of these materials and the possible spread of diseases. From the published articles it appears that the danger of bacterial infection has been overemphasized, but the question of ascaris eggs survival, particularly in incomplete or improperly treated sewage and sludge, requires further investigation. The astounding statement that *E. histolytica* is prevalent in 20 per cent of the population of the United States indicates that this type of infection is of great importance. It has been fairly well established that this organism does not remain viable for long in sewage and sludge or when applied to vegetables, but the possibility of infection by untreated sewage remains in addition to other means of transmission.

The presence of detergents in sewage, in general, considered a nuisance problem at present, may be of particular importance when present in large quantities in sewage and industrial waste mixtures. The debate concerning its importance has by no means been settled or solved the problem.

Attention should be called to the interest in sewage and effluent reclamation for water supplies and industrial purposes. Ground-water replenishment in semi-arid regions is probably only the first step in reclamation, because with increased population and industrial activities the demand for more water increases.

The literature did not reveal marked changed, improved, or new sewage treatment processes, but indicated a steady progress in minor modifications and a gradual firm establishment of principles. The theory and mechanism of various processes utilized successfully for many years is beginning to catch up with practice. Undoubtedly, when the mechanism of various existing processes is better understood, possibly new and certainly improved methods will result.

Among the industrial wastes, particular attention is called to radioactive wastes. An indication is obtained of the growing importance of this waste and the amount of material published on the subject by the fact that last year there were only 5 published articles reviewed, whereas this year attention is called to 59 references. The increase in references is primarily the result of the release of more and more nuclear science literature by the Atomic Energy Commission. With release of more information the potential hazards of this waste will be better understood, thereby allaying the instinctive fear of some unknown danger, stimulating technical training to cope with potential hazards, and aiding in developing methods for removal of radioactive elements from dilute wastes.

The intense interest and importance of stream pollution is indicated by the large number of references to legal aspects of the problem. Never before have there been inaugurated so many studies and have there been made available such large sums of money for study and abatement of the problem.

For many years sewage treatment plant operators have been concerned with odors from filters, tanks, dryers, and incinerators. Expansion of industries with liquid wastes may increase the problem. The treatment and disposal of industrial gases, vapors, and fumes, frequently resulting in a different type of liquid waste, must be considered more and more. There is a very narrow margin between converting gaseous waste to liquid waste and the whole problem of disposal and treatment of waste material dispersed into the atmosphere. The problems are so closely related that more attention should be given to allaying the disposal of gaseous and liquid wastes.

GENERAL

Biology

The clearing of turbid waters by means of ciliate carchesium was demonstrated by Sugden and Lloyd (577). This mechanism is concerned with the method of feeding and subsequent ejection of digested substances forming dense masses bound together with mucus. If the particles are nutritious they are digested and then ejected. Undigestible particles are also ejected, but after a shorter period. These ejected particles, unlike their original dispersed state, are relatively large and settle readily. The authors were able to obtain clarification of India ink suspension by the activity of this organism in two hours. The organisms also bring about aeration of the liquid by their strong ciliary movements.

The role of microscopic green organisms as agents of sewage purification and their deliberate cultivation as a means of sewage disposal is suggested by Stone and Abbott (574) and Abbott (2). The suspended solids in the settled sewage are settled as sludge, but the growth of the green organisms replaces the suspended solids in the original liquor. Despite the increase in organic matter (B.O.D.) resulting from growth of green organisms, there is a favorable D.O. balance due to the photosynthetic reaeration. The incorporation of the green growths as slimes, adhering to the bottoms and sides, would produce clear effluents. The activity of the green organisms converts the soluble forms of nitrogen in sewage to organic nitrogen.

Nutritional requirements of bacteria are again emphasized by Helmers *et al.* (289) from the standpoint of design and operation of biological treatment plants for the stabilization of industrial wastes and industrial waste sewage mixtures.

Allen, Brooks, and Williams (11) studied the effect of sewage treatment on the numbers and types of bacteria. Total plate counts, coli aerogenes bacteria, and *Streptococcus faecalis* were higher in settled sewage in the warmer months than in the colder

months. A plant equipped with bioaeration, trickling filters, and humus tanks reduced the bacterial numbers by about 80 per cent over the settled sewage. At another plant, where the rate of treatment was much lower, about 90 per cent reduction of bacterial numbers was affected by trickling filters and humus tanks. The final effluents from the treatment plants still contained large numbers of bacteria. The effluent from the underloaded plant, which discharged a chemically acceptable effluent, contained 1,600 per ml. of faecal *B. coli* and 200 faecal *Streptococci* per ml. The reductions by effluent polishing filters (sand and anthracite) could not be relied upon to produce an effluent of good bacterial quality (also see section on "Water Pollution").

Disease

Wide interest is manifested in the occurrence and survival of pathogenic organisms in sewage and sludge and the possibility of spreading of diseases by the utilization of these materials on land for growing of crops. A review of the literature presented by Rudolfs, Falk, and Ragotzkie (525) includes over 110 references on the occurrence and survival of *Salmonella* types and the colon aerogenes group in soil, water, sewage, sludge, and vegetation. A similar review by the same authors (526), dealing with animal parasites, includes about 60 references.

The survival of *E. coli* in stored wet digested sewage sludge and sludge undergoing drying was studied by Fuller and Litsky (241). The organism survived for 7 weeks at 37° C., and for 2 weeks at 22° C. Of the various factors affecting the survival of *E. coli*, such as temperature, moisture, pH, antibiotic agents, and bacteriophage, the competition with other organisms is considered the more important factor. It is concluded that the absence of *E. coli* from dried sludge should be considered adequate insurance against danger from such pathogenic intestinal types of bacteria as the bacilli of typhoid fever and dysentery. The chlorination of raw and digested sludge with the object of disposal of sludges with the effluent into large bodies of water was studied by Tyler, Orlob, and Williams (605).

A cultural method for the quantitative enumeration of tubercle bacilli for the study of the survival of these organisms in sewage and sewage treatment processes was reported by Pramer, Heukelekian, and Ragotzkie (484) (485).

Mom (419) reported, on the basis of microscopic and growth characteristics, the presence of alcohol-fast bacteria resembling tubercle bacilli in ditches receiving sanatoria wastes. Cattle grazing in the meadows in the vicinity were contracting tuberculosis. Six months after the sanatorium was closed no tubercle bacilli were found in the ditches. Effluent of a septic tank and sewage from several sanatoria showed tubercle bacilli. It was concluded that sewage from sanatoria should be considered as a possible source of infection for man and animals. It is stated that interchange of human and bovine tuberculosis is possible through direct or indirect contact (for example, through infected water).

Successful isolations of tubercle bacilli from effluents of sedimentation basins of sanatoria, and canal water and mud receiving the discharge from sanatoria, was reported by Monaci (420).

The occurrence in Montana of four cases of tularemia associated with domestic water supply was investigated by Jellison, Epler, Kuhns, and Kohls (327). It was demonstrated that the water supply was contaminated with *P. tularenses*.

It is reported (84) that *E. histolytica* is prevalent in 20 per cent of the population of the United States. The physiology of *E. histolytica* and

the kinetics of heat destruction of the cysts were studied by Chang (167) (168). In addition to contact time and temperature, the concentration of the organisms should be considered, especially when the conditions are such that the rate of destruction is low. It is stated that immersion of vegetables in water at 45° C. for 30 min. does not provide much margin of safety for the destruction of the cysts, but a temperature of 50° C. is preferable.

Orenstein (449) discusses the hazards of ascaris infection from sewage. In infected communities, ascaris ova are found in sewage effluents unless filtered, and in digested sludges. Sand filters remove the ova mechanically without affecting their viability. The author cites the experience in South Africa in regard to the consumption by natives of vegetables grown on sewage irrigated farms over a period of years during which time there has been no unusual prevalence of intestinal diseases. Most vegetables were eaten after cooking.

Robinson (512) on the basis of experience in South Africa, concludes that consumption of water containing sewage is non-injurious to animals. Experience has shown that grazing cattle on sewage farms does not cause human or animal epidemics. The incidence of mastitis on sewage farms is not greater than on other farms.

Abbott (1) also concluded that controlled grazing of cattle, as practiced at Capetown, should not constitute a potential menace to health and the milk produced on such farms could be used.

A large percentage of ova of intestinal parasites remain viable after digestion and air drying of sludge according to Hogg (304). A moisture content of 5.5 per cent is necessary to insure the destruction of ascaris ova. Experiments showed that nematode ascaris ova in digested sludge, spread out for atmospheric drying, were destroyed in 1.5-in. layers, but in 3-in. to 4.5-in. layers there were viable ova left, although their numbers were greatly reduced. It was concluded that sun drying of sludge in thin layers for long periods was effective in destroying the ova.

Reinhold (501) discusses the problem of roundworms in Darmstadt, Germany. The incidence of roundworm infection was 89 per cent. Roundworm infection is caused by the use of untreated or improperly treated sewage as fertilizer for vegetables. The sewage contained 5 to 6 worm eggs per ml. The author suggested as an abatement and prevention program (a) systematic medical treatment of infected people, (b) installation of mechanical sedimentation tanks to remove the eggs from the sewage, and (c) anaerobic digestion of the fresh solids followed by composting and dewatering on drying beds.

Mathematical and Statistical Applications

Several articles have appeared this year dealing with mathematics and statistics and their relation to sewage, industrial wastes, and stream pollution. Bushee (144), in an article on mathematical relationships in sewage treatment, attempts to correlate the biological reactions involved in oxidation, reduction, and sludge digestion. By mathematical deduction and analysis he shows that by the selection of proper constants a single mathematical formula can express these three reactions.

In a series of three articles on the graphical approach to statistics by Velz (624) (625) (626) the nature of variability of data is discussed and methods are shown for drawing simple probability curves, from which confidence limits as to the accuracy of the data can be determined. He further discusses the use of normal and skewed probability papers. By a simple plotting of the data on normal log probability graph paper, it is possible to

determine the mean, the standard deviation, and the confidence limits. It is also possible to determine whether the data follows the law of probability or whether it is affected by variations other than normal measurement errors. Engineers and laboratory investigators who do not normally use statistical methods to evaluate data should find the simplified statistical methods proposed in these articles particularly valuable.

Detergents

Jepson (331) considers the problem created by the presence of detergents in sewage as a serious one and warns that these detergents are not only difficult to remove but also affect the character of the sewage so as to make the removal of other polluting matter more difficult.

Seiver (545), employing Teepol (an anionic detergent containing 20 per cent active matter) in concentrations of 200 to 500 p.p.m., which he considers to be 4 to 10 times the maximum expected in the next five years, found a progressively adverse effect on sedimentation.

Degens *et al.* (194), in a study of the effect of detergents on the anaerobic fermentation of sewage sludge, observed that at concentrations of less than 500 p.p.m. active material of several detergents (anionic and nonionic types) no interference with digestion was incurred. The yield of methane per gram of carbon was the same for Teepol as for a fatty acid soap. However, a smaller amount of detergent than soap is incorporated in the sludge, producing a lower methane yield. In correlating the filterability of digested sludge and the presence of detergents, these workers demonstrated that sludge filterability decreased when the concentration of detergents in the raw sludge exceeded 500 p.p.m. active material.

Evans and Winsor (224) reported that replacement of soap by Teepol would not cause any difficulty in the cracking of wool scouring liquor if "alumino-ferric" were added prior to acidification. Clear effluents of negligible grease content were produced. About two-thirds of the Teepol was removed from the scouring liquor during the cracking process. In the case of Bradford sewage, which contains wool scouring liquors, they indicated that the possible effect of synthetic detergents at their present level was small in relation to the effect of other variables. "Alumino-ferric" used as an auxiliary precipitant would provide a technical solution to any serious difficulty in sewage processing arising from an appreciable increase in Teepol consumption. The "alumino-ferric" would not cause an increase in the bulk of the sludge while the quality of tank effluent would be greatly improved.

According to the results of Goldthorpe and Nixon (259), the presence of 200 p.p.m. of Lissapol (nonionic) and Teepol (anionic) diminished the effect of acid precipitation of the sewage and a carry-over of a greater load to the biological plants ensued. Application of sewage with 200 p.p.m. detergents to laboratory trickling filters induced a slow, cumulative deterioration with ponding after four months of continuous feeding at 100 g.p.d. per cu. yd. In three short series of activated sludge experiments, the authors demonstrated the poorer quality of the effluents in the presence of 200 p.p.m. detergents under similar conditions of aeration. Extended aeration periods were deemed essential.

An investigation of the effect of synthetic detergents on certain water fauna by Degens *et al.* (193) showed that an active material concentration of 5 p.p.m. of various anionic and nonionic agents had a lethal effect on tadpoles, sticklebacks, and daphnia after 10 to 100 hr., depending on the species of fauna and the type of detergent. Anionic detergents of the

alkyl sulfate group were quickly decomposed in an aquarium tank, the active material content dropping from 25 to 3 p.p.m. within four days. The biological decomposition of an alkylaryl sulfonate and of a nonionic type (polyglycol ether of an alkylated phenol) proceeded much more slowly, the active material content dropping from 25 to 10 to 15 p.p.m. in 14 days. It was concluded that the lethal concentration of 5 p.p.m. of active material of a detergent would be diluted to such an extent upon discharge into a river that any harmful effect on fishes would be obviated. Fish became acclimatized to fairly high concentrations of synthetic detergents.

In large-scale experiments at the Coven Heath sewage works, Hurley (321) found no effect with 50 to 75 p.p.m. Teepol on any stage of the sewage purification process, which included primary sedimentation, trickling filters, and secondary sedimentation. No adverse effect on the final effluent or the receiving stream was observed. In laboratory experiments no appreciable interference was found in the settling of sewage with concentrations of Teepol up to 300 p.p.m.

Cross (184) experienced interference with chemical coagulation of Lake Michigan water by the presence of 3 to 5 p.p.m. of household and industrial detergents. In general, the household types of synthetics had a greater inhibiting action than the industrial types.

Waddams (631) discussed synthetic detergents, in general, as to their properties and uses. He reviewed the work done by the Shell Chemicals Ltd. scientists and believes that "in the light of the facts presented, no unmanageable problem is likely to arise from the extending use of synthetic detergents and the position from the sewage engineers point of view is safeguarded by the existence in exceptional cases of specialized means of treatment."

Odors

The tolerance of sulfate-reducing bacteria to hydrogen sulfide was investigated by Miller (407). He found that a maximum of 2,500 p.p.m. of hydrogen sulfide could be produced by sulfate-splitting bacteria under optimum conditions. Experiments showed that the exposure of these organisms to 2,700 p.p.m. of hydrogen sulfide had no deleterious effect on subsequent hydrogen sulfide production upon transfer to a new medium. Removal of hydrogen sulfide from the culture resulted in a further production of the gas, indicating that the presence of hydrogen sulfide is a deterrent to further production. The age of the culture also has an effect on the rate of hydrogen sulfide production. The same author (408) reported that the addition of metal salts of antimony, bismuth, cobalt, cadmium, iron, lead, nickel, and zinc gave growth and production of sulfides of the metals with the exception of copper. The quantity of sulfides produced was greater when insoluble sulfides were formed.

Allen (10) studied the numbers of sulfate-splitting bacteria in sewage and the increase in numbers upon incubation. Development of sulfide was favored by neutral or alkaline reactions and at pH 5.0 the inhibitory effect was considerable. A chlorine dose of 50 per cent of the demand delayed the onset of septicity for two weeks. A similar retardation was produced by 18 p.p.m. TNT and 8 p.p.m. of picric acid, nitrobenzene, and dinitrobenzene. The mechanism of inhibition of sulfide production by nitro compounds was attributed to the delay of lowering the oxidation-reduction potential to a level favorable for the development of sulfate-reducing bacteria.

Nagano (437) gives evidence that sulfide is oxidized to sulfate by chlorine and not to sulfur, as commonly accepted.

Davy (189) concludes that the conditions necessary for the prevention of build-up of sulfides in sewers can be approximately stated in terms of Reynolds number, the B.O.D., the temperature, and the geometry of the sewage cross-section.

The problem of controlling odors and insects in sewers in Houma, La., is discussed by Gary (246). Flat sewer grades and hot climate created a serious odor problem. Cloroben was applied to the sewers at a concentration of 10 p.p.m. for a few days as a shock dose and thereafter at 2 p.p.m. Control of odors and roaches is reported to have resulted.

ANALYTICAL METHODS

Biochemical Oxygen Demand

Buswell *et al.* (145)(146) emphasize the fact that interpretation of B.O.D. data has been complicated by the occurrence of nitrification within the five-day period. They found that 97 per cent nitrification could be accomplished in five days when an actively nitrifying seed was present. In order to determine the various forms of nitrogen present, as well as the dissolved oxygen, a two-compartment incubation vessel was used. The contents of the two compartments were mixed by inversion before running the necessary analyses.

In an attempt to suppress nitrification in the B.O.D. test, Mohlman *et al.* (418) studied various modifications, which included acid and heat pasteurization and the addition of chromium. The latter appeared to affect the entire flora and fauna present. Acid pasteurization followed by pH adjustment and reseeding seemed to conform more closely to the desired distinction between nitrifying and nonnitrifying samples.

Lewin (374) made a detailed study of the factors involved in the determination of B.O.D. The factors studied included temperature variation, bottle size, dilution water, nitrification, and reagents used.

Strong *et al.* (576) and Swope and Kenna (583) studied the B.O.D. of a number of organic compounds found in industrial wastes, such as aldehydes, acids, formates, amines, etc. It was found that with those compounds normally toxic to bacteria the B.O.D. increased with increasing dilution, a phenomenon which has been noted by other investigators.

Swango and Lamb (580) describe an apparatus in which several dilutions may be made for the B.O.D. test with a minimum of aeration. They also claim that dilutions can be made in less time than with the ordinary procedures used. Wolfe (655) constructed a nomograph for calculating the proper dilutions, based on the probable B.O.D. of the sample.

The question of using the proper seed for the determination of the B.O.D. of industrial wastes is considered by Gehm (249) in connection with pulp and paper mill wastes. He concludes that the organisms contained in the bottom sediment of the receiving stream are best suited for an inoculating media. Sawyer *et al.* (538) propose the use of C.P. glucose and glutamic acid as primary standards in the B.O.D. test.

Oxygen Consumed

Interest was continued on the determination of oxygen consumed and its relationship to B.O.D. Rhame (502)(503) discussed the use, interpretation, and interrelationship of B.O.D. and oxygen consumed. He also presented the correlation he obtained between the ultimate B.O.D. calculated from three- and six-day observations and the oxygen consumed as determined by a dichromate method. He corrected the oxygen consumed values by subtracting a factor, obtained by multiplying the NH_3–N by 2.61.

Schroeder (543) modified the alka-

line permanganate method of oxygen consumed by adding nickel nitrate, which he claims acts as a catalyst in the back-titration of excess permanganate. Skopintsev (561) used a mixture of potassium and silver chromates and chromium trioxide in a sulfuric acid solution for the oxidation of organic material in water. He states that 30 to 150 gammas of organic carbon can be accurately determined by this method. In some of the dichromate oxygen consumed methods the excess dichromate is titrated with ferrous salts, using barium diphenylamine sulfonate as an indicator. Swaine (579) pointed out that when 0.1 N dichromate is used, an end-point correction of 0.3 ml. should be applied.

Dissolved Oxygen

Cameron (158) discussed the factors involved in the determination of dissolved oxygen by the Rideal-Stewart method in the presence of industrial wastes. He recommends that when gas liquor is present the Rideal-Stewart modification be replaced by the Alsterberg modification of the Winkler procedure.

Arnott *et al.* (92) determined traces of dissolved oxygen by treating a 1,000-ml. sample by the regular Winkler procedure. The liberated iodine was extracted with CCl_4. To the extract was added an excess of 0.02 N $Na_2S_2O_3$ and the excess determined by back-titration with 0.02 N I_2. A maximum probable error of $\pm$ 0.002 ml. of oxygen is claimed. Another approach to the dissolved oxygen determination was made by Gad (244) who treated the sample with $MnCl_2$ and NaOH. The supernatant was siphoned off and the precipitate treated with sodium pyrophosphate and H_2SO_4. The manganic ion was then titrated with $MeSO_4$, using diphenylamine as an indicator. In waters containing industrial wastes, in which the hypochlorite modification normally would be used, Seaman and Allen (548) used a polarographic method. Higher dissolved oxygen values are claimed for this method by the authors. Pieters and Hanssen (472) used a colorimetric method, in which the intensity of the blue starch-iodide color was determined spectrophotometrically.

Nitrogen

Continued interest was shown during the year in the determination of the various forms of nitrogen. Johnson and Ulrich (332) oxidized the organic material present with H_2O_2 before carrying out the nitration of phenoldisulfonic acid in the determination of nitrates. These authors, as well as Taras (587), used NH_4OH instead of KOH for the color development. Taras (587) removed chlorides by precipitation with a silver salt and when the colors were compared visually, 2.0 ml. of phenoldisulfonic acid was added to each standard. Barnes (104), as well as Holler and Huch (307), used the isomeric xylenols in the nitrate determination. The former nitrated the xylenol in an acetic acid solution, then extracted the mixture with toluene. The aqueous layer was made alkaline and the developed color determined photometrically. A sensitivity of 0.1 gamma of nitrate N is claimed. The latter authors carried out the nitration in an H_2SO_4 solution and steam distilled the nitrated xylenol into caustic. Several other workers (8) (245) (243) tried various modifications of the brucine method for the nitrate determination; all noted considerable interference in the use of this method. Sánchez (534) and Ubaldini and Guerriere (606) used other methods for determining nitrates in the presence of nitrites. The latter workers first converted the nitrites to nitromethane, which was extracted with CCl_4 or $CHCl_3$.

The determination of Kjeldahl nitrogen was also investigated by many workers. Kirk (346) considered many

of the factors involved in the determination of Kjeldahl nitrogen, especially the factors concerned with the digestion process. Day *et al.* (191) and Doyle and Omoto (206) were primarily concerned with the determination of microquantities of Kjeldahl nitrogen. Instead of using the conventional absorbents for the distilled ammonia, Blom and Schwartz (117) used nickel ammonium sulfate and titrated the excess to the methyl-red end point. Machemer and McNabb (389) claim that steam distillation of the NH_3 has advantages over the conventional methods. A 15-fold excess of caustic was found to be sufficient for rapid and complete distillation of the NH_3. Klein (349) used an indicator mixture composed of bromcresol-green and methyl-red in the back titration of the excess boric acid. Direct Nesslerization of the NH_3–N in sewage, instead of distillation, was used by Houlihon (315), who claims that comparable results can be obtained. Errors caused by the use of NaOH were avoided by substituting sodium hexametaphosphate.

Grease

In the determination of grease in sewage sludges, Stephenson (571) dehydrated the grease with $MgSO_4 \cdot H_2O$ and then extracted it with petroleum ether.

Anions

Hach (275) described a "drop" method for the determination of hardness, alkalinity, chlorides, sulfates, etc., in water. With proper precaution, an accuracy approaching 5 per cent can be obtained. West *et al.* (639) discussed the application of flame spectrophotometry in the analysis of water samples. The occurrence of lead in drinking water has long been of sanitary significance. The usual dithiozone method for its determination is subject to many interferences, but Buczowska (138) describes a method for its determination in which iron, magnesium, copper, and zinc do not have to be removed.

Plant Control Tests

Several papers (222) (584) (325) were published dealing with the analytical procedures to be used in the evaluation of industrial wastes and sewage treatment plant efficiencies. Eckenfelder and Hood (210)(212) (211) followed the course of oxidation of sewage by means of alkalinity measurements and the determination of nitrogens. These same authors (209), as well as the 1949 FSIWA Operators' Forum (239a), discuss the tests to be applied in following the efficiency of a sewage treatment plant. Riehl and Will (509) reviewed the analytical determination of metals affecting sewage treatment. Among the determinations discussed are those for iron, copper, nitrate, chromium, zinc, cadmium, and cyanide.

pH

Bates *et al.* (107) studied various pH standards and concluded that the present buffers give errors of –0.02 to –0.05 at pH values above 11.0 and ± 0.03 below pH 2.5. They list several buffers that they recommend as standards. Tuddenham and Anderson (603) developed a calcium chloride-hydroxide system that can be used in the pH range 11.0 to 12.65.

Turbidity

In the measurement of low turbidities, Matheson (395) describes a double-cell photoelectric turbidimeter operated from a storage battery.

Metallic Ions

Methods for the colorimetric determination of cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc were developed by Butts *et al.* (152).

The metallic ions are of importance, not only from the standpoint of drinking-water standards, but also in in-

dustrial wastes and sewage treatment. Copper was determined in microquantities by the use of a pyridine-salicylic acid reagent by Gordieyeff (263). Delavault and Irish (195) used dithiozone in an ammonical solution for the detection of copper in natural waters.

Smith *et al.* (564) state that in the determination of aluminum with aluminon the pH of the final mixture is important. They discuss extensively the preparation and conditions under which aluminon must be used. Back and Raggio (97), in using the alizarin-S method for the determination of aluminum, found that in the absence of calcium, hydroxylamine-HCl would eliminate interference from ferric iron.

Adamovich (4) found that from 5 to 20 p.p.m. of magnesium could be determined by varying the amount of titan-yellow used, depending upon the amount of magnesium present. Shraibman (555) also studied the factors involved in using titan-yellow for the determination of magnesium. He obtained the best results when the NaCl concentration was 6.0 grams per liter and the NaOH was 0.2 N. Hulth (318), in separating calcium from magnesium when more than 25 per cent Mg is present, adds the solution containing the calcium and magnesium to an aqueous solution of ammonium oxalate, which is 0.05 N in acetic acid. Ringbom and Merikanto (511) describe a method for determining calcium in which the sample is titrated with sodium fluoride. Ferric thiocyanate is used as an indicator. The optimum pH is 2.5 to 3.5.

Another metal of sanitary significance is chromium. Many methods have been proposed for its determination in recent years. LaCroix and Labalade (361) used KIO_4 as oxidizing agent, instead of the usual bismuthate and persulfates. Urone and Anders (607) carried out the oxidation of the trivalent chromium with alkaline-bromate. However, they use NaOH instead of NH_4OH, resulting in a higher pH and more complete oxidation.

McConnell and Ingols (400) modified the "Standard Method" sulfate determination using benzidine hydrochloride so that greater accuracy could be obtained and the range of determinable sulfate concentration increased.

In the determination of chlorides and bromides with $AgNO_3$, Schafer (539) uses N-methyldiphenylamine-red as an adsorption indicator. At the equivalence point the color changes sharply from a slight violet tinge to a red-violet color. Stalzer *et al.* (570) found that the presence of protective colloids (such as gelatin, dextrin, etc.) enabled more precise results to be obtained in the chloride determination. Swift *et al.* (582) propose a modification of the Volhard method in which the Cl^- is titrated with $AgNO_3$ in a neutral or dilute HNO_3 solution to a clear point. $FeCl_3$ is then added and the mixture titrated with HCNS to a pink color. The excess HCNS is titrated with $AgNO_3$ to the disappearance of the pink color.

Willard and Horton (645) made an exhaustive study of the various indicators that could be used in the titration of fluoride with thorium nitrate. These same authors (646) describe the fluorometric determination of fluoride in which quercetin is used as an indicator. The titration is carried out at pH 3.0 in a 50 per cent alcohol solution. From 0.1 to 40.0 mg. of fluoride can be determined by varying the procedure.

Thrun (596) used eriochromecyanine R.C. in the colorimetric determination of fluoride. When interfering ions, such as Fe (1 p.p.m.), Ca (above 106 p.p.m.), and SO_4 (760 p.p.m.), are present the distillation procedure must be used. The precision in the lower fluoride concentration is less than 0.05 p.p.m. and in the higher range 0.25 p.p.m.

Chlorine

A method for the determination of free chlorine or bromine was proposed by Milton (413). It is based on the formation of cyanogen chloride or bromide, which is reacted with a pyridine-benzidine reagent. Golubev (260) reacted free chlorine with tris (p-dimethylaminophenyl) methane trihydrochloride and obtained a violet color. The color also will develop in the presence of chloramines if the solution is first boiled. Taras (589) describes a simplified method for the calibration of photometric instruments for the determination of residual chlorine. With the increased use of chlorine dioxide, methods have had to be developed for the determination of the various entities present. Aston (94) discussed the use of ClO_2 and the methods used in determining the residuals present.

Cyanides

The errors encountered in the determination of cyanide have been subjected to further work. Urusovskaya and Zhilina (608) determined cyanide by titration of the ammonical solution with nickel ammonium sulfate, using dimethylglyomime as indicator. When all of the cyanide is complexed with the nickel, the red color of nickel glyoxime appears.

Phenols

Phenol and its homologues are constituents of many industrial wastes and quite often are the cause of tastes and odors in drinking-water supplies. A number of methods have been proposed for the determination of phenolic compounds. Ettinger and Kroner (223) and Riehl and Will (508) discuss the techniques first necessary for separation of such compounds and the subsequent analytical procedures used in their quantitative determination.

SEWAGE TREATMENT

Sedimentation

Jenkins, Hewitt, and Winsor (328) reported detailed observations on the settling of three types of sewage in large rectangular tanks. In one case, sewage containing industrial waste and secondary sludges was settled in a mechanically desludged tank and no deterioration in the quality of effluent was caused by suddenly trebling the normal flow with a retention time of 1.8 hr. In another test, sewage containing industrial waste was passed through settling tanks of poor design (poorly arranged inlets and baffles, accumulation of heavy sludge in the inlet, high surface velocity, and high overflow rates) and the performance could be described as moderate with 1.2- to 1.8-hr. retention. In a third set of tests the effluent from the primary tank was mixed with surplus activated sludge, aerated, and passed through rectangular secondary tanks. With 7.8-hr. retention, the results were excellent; with 2.6-hr. they were good; at 1.4 hr. they were for the most part acceptable.

The total amount of suspended matter does not provide a reliable measure of the performance of a sedimentation tank. No evidence was found that high velocities through settling tanks caused disturbance of the settled sludge. It is suggested that the presence of an excessive amount of settleable solids in an effluent is due to the failure of matter to settle out and not to a disturbance of the sludge in the bottom. The results suggest the possibility of the removal of nonsettleable matter during sedimentation due to flocculation. Vertical temperature variations in sedimentation tanks could not be observed and were not considered responsible for the variations in performance.

The flow was observed in model tanks having one glass side and simulating modern sedimentation tanks.

With known inlet systems the liquid was not distributed rapidly enough over the cross-section of the basin. An inlet system was devised whereby the liquid enters the basin at one end by means of inclined T-end pipes arranged so that the openings of horizontally adjacent pipes face one another. Complete distribution over the entire cross-section of the tank was achieved in a distance equal to half the depth of water. A 95.9 per cent detention efficiency (actual detention period over theoretical) is claimed. The system is also applicable to circular sedimentation basins.

Two interesting articles on methods of studying the performance of sedimentation tanks for the purpose of improving their design have appeared during the past year. Rohlich and Ingersoll (517) describe the dispersion testing method for determining the hydraulic behavior of gravity separators in both the sedimentation and flotation process. They conclude that "the studies conducted thus far show that an overflow weir and vertical baffle influent configuration produces severe mixing and short circuiting . . . while a horizontal slotted baffle replacing the simple vertical baffle results in greatly improved hydraulic characteristics." Archibald (90) describes the use of radioactive tracers in studying flow characteristics of sedimentation tanks. He states that this method "gives a more accurate picture of the actual flow-through curves of basins and conduits by bringing out the longer tails of the (flow-through) curves which go undetected by other means. . . . In many cases, especially in model studies, the radiotracer may be followed through the system without disturbing the flow pattern, by taking readings through pipe or tank walls."

On sedimentation tank design, Poepel (475) has developed equations describing the sedimentation process based on methods similar to those proposed by Hazen. Constants in his equations are evaluated by use of data from well-operating treatment plants. Rice (504) has compiled an interpretation of recent regulations and recommendations of several State Boards of Health in regard to the design of primary settling tanks.

Morgan and Miller (425), comparing the relative performance of conventional and upflow settling basins treating the same raw water, conclude that: "1. Operation of upflow basins is more complex, requiring more control and operator attention than conventional basins. 2. Combined annual expense of amortizing and operating plants with upflow units is less than plants with conventional units with mechanical sludge removal. 3. Upflow units are sensitive to raw-water temperature increases when the rate of change is greater than one degree per hour."

The U. S. Soil Conservation Service (86) has published an annotated bibliography on sedimentation which is estimated to contain well over 90 per cent of the more important articles published in English prior to January 1, 1950; also many unpublished theses and translations of foreign-language articles. Both an author and topic index are included.

Chemical and Mechanical Methods

Kominek (353) reviews methods used for flocculation and sedimentation of sewage, the chemicals most frequently employed, and describes several plants, mainly those treating industrial wastes.

Williamson (649) describes the results of nine months' operation of a plant using the Daytona Beach process. Calcium carbonate sludge from the nearby water softening plant is used as a coagulant, and flocculation, coagulation, and sedimentation are achieved in one small tank. Using 0.1 cu. ft. of air per gallon of sewage with the calcium carbonate, B.O.D. re-

movals of 60 to 65 per cent and 80 to 85 per cent are obtained with 1-hr. and 2-hr. detention times, respectively.

Pettet, Collett, and Summers (471) describe studies made by the (British) Water Pollution Research Laboratory on the use of specially designed rapid filters for additional treatment of sewage plant effluent. Two units, one containing sand between 10 and 18 mesh per inch and the other anthracite between 4 and 18 mesh, were operated in parallel at the rate of 100 gal. (Imp.) per sq. ft. per hr. Reductions in suspended solids and B.O.D. were 67 to 92 and 47 to 78 per cent, respectively, in the sand filter. Slightly better results were obtained with the anthracite filter. About 3 per cent of the total effluent was used for backwashing the filters at 24-hr. intervals at the rate of 700 gal. (Imp.) per sq. ft. per hr. Accumulations of gelatinous matter were avoided in later installations by loosening the sand before backwashing by blowing air into the bottom of the filters.

Effect of mechanical filtration of sewage effluents through sand or anthracite filters on the bacterial population was studied by Allen, Brooks, and Williams (13). It was concluded that although such filtration appreciably improved the bacterial quality of the effluent, it cannot be relied upon to produce an effluent of good bacterial quality.

Studies were also made on the use of micro-strainers consisting of woven stainless steel fabric in the form of a drum open at one end and with about 60 per cent of its surface submerged. Two meshes, Mark II and Mark IIA, with openings of 58,000 and 100,000 per square inch and nominal wire diameters of 0.06 and 0.045 mm., respectively, were used. Humus tank effluent entered the open end of the drum and debris removed collected on a trough inside. At rates of flow of 312 to 364 g.p.h. (Imp.) per square foot of submerged area the suspended solids and B.O.D. reductions were 61 to 73 and 31 to 46 per cent, respectively, for the Mark II screen. Better results were obtained with the Mark IIA screen using a rate of 416 g.p.h. (Imp.) per square foot. About 7 per cent of the effluent was used for continuous backwashing, and chlorination at 3- to 8-day intervals was necessary to control organic growths on the mesh.

Jenks (329) reviews the vacuum flotation process and describes installations in California.

Barry (105) describes an experimental laboratory-scale model of a Dorr Clariflocculator installed at the New Haven, Conn., primary sewage treatment plant. "Recorded results indicated that it would be reasonable to expect an increased reduction of solids of from 8 to 10 per cent over that accomplished in the same sewage at the existing plant."

Biological Filters

At Liberty, N. Y., one of the first bio-filter plants in the Eastern U. S. was put in service in 1940. This plant, in addition to containing primary settling tanks, is provided with two octagonal filters, each 3 ft. deep, which are operated in series under heavy loads in summer and in parallel under light loads in winter. One of the distinctive features of the operation is that the volume of recirculated sewage has been held constant. Borden *et al.* (123) report that the raw sewage in 1946 contained 367 p.p.m. of B.O.D. and the secondary clarifier effluent 27 p.p.m. In 1948 the rate of application on the primary filter was as high as 25 m.g.a.d. and on the secondary filter 23 m.g.a.d. The authors state that circular filters would have been preferable to octagonal ones, as flies breed more readily in the unused corners in summer and ice forms more quickly in winter.

A study was made in 1946 of the operation of the sewage plant serving Centralia, Mo. (422), where a primary

settling tank, a trickling filter 3 ft. deep, and a final settling tank are in service. Tests of the operation of the plant were made for four one-week periods. During the first period there was no recirculation of sewage; during the second and third periods final effluent and trickling filter effluents, respectively, were pumped back into the primary tank influent; during the fourth period final settling tank underflow was pumped back into the influent flowing to the primary settling tank. The best results were obtained during the fourth period. The overall plant efficiency during this period resulted in 93 and 91 per cent removal of B.O.D. and suspended solids, respectively, with a final effluent containing 14 p.p.m. of B.O.D. and 27 p.p.m. of suspended solids.

At the bio-filtration plant serving Plainview, Minn. (423), studies were made of plant efficiencies during normal loads and during the canning season, when the loads due to corn canning wastes were excessive. The plant contains, in addition to primary, intermediate, and final settling tanks, two trickling filters, each 6 ft. 3 in. deep. During the non-canning period, when the flow averaged 0.117 m.g.d., the B.O.D. was reduced from 320 to 21 p.p.m. and the suspended solids from 183 to 30 p.p.m. The B.O.D. loadings on the primary and secondary filters were 0.456 and 0.110 lb. per cu. yd., respectively. During the canning period, when the average flow was 0.462 m.g.d., the B.O.D. was reduced from 1,566 to 466 p.p.m. and the suspended solids from 1,097 to 65 p.p.m. The B.O.D. loadings of the primary and secondary filters were 14.8 and 7.9 lb. per cu. yd., respectively.

Grantham *et al.* (267) studied the performance of four small experimental trickling filters, which varied in depth from 6 to 8 ft. The filter media consisted of furnace slag, waste pine wood, limestone, and gravel. The volume of settled sewage applied to the beds varied from 2.2 to 7.0 m.g.a.d. Samples at 2-ft. intervals in the bed and of the settled effluent were collected. The investigation substantiated the basic law of Velz that "the rate of extraction of organic matter per interval of depth of biological bed is proportional to the remaining concentration of organic matter measured in terms of its removability." The investigations revealed that it may be more economical to use 4-ft. instead of 6-ft. depth of filters in southern areas. Nitrification in the filters followed the monomolecular reaction pattern and depended to some extent upon the medium used and the rates employed.

Anderson (18) investigated the amount of oxygen absorbed by the spray from a Columbus nozzle on the trickling filters at Brockton, Mass. He found that the absorption by the spray increased as the distance from the nozzle became greater. In general, the dissolved oxygen in the sewage at the nozzle was zero and at a distance 9 ft. from the nozzle it varied from about 1.4 to 4.7 p.p.m. After passing through 9.5 ft. of filter medium the D.O. averaged 6.0 p.p.m.

According to Flood (233), at Bristol, Conn., two high-rate trickling filters, each 92 ft. in diameter and 6 ft. deep, have been designed to treat an average flow of 3.5 m.g.d. of settled sewage and a maximum flow of 8.0 m.g.d. The filter medium is trap rock graded in size from 1¼ to 3½ in. At average flows the loading on the filters will be 11.5 m.g.a.d., or 1.6 lb. of 5-day B.O.D. per cu. yd. of filter stone. Following the filters there are three sewage pumps that can return a portion of the flow to the primary settling tank influent or can pump the entire flow to the final settling tanks.

The new sewage plant at Winchester, Va., is provided with two high-rate trickling filters designed to operate in series. Klegerman (348) states that two-stage bio-filtration was adopted to produce an effluent with a

high degree of purity and to handle satisfactorily a greatly fluctuating industrial load with marked variations in the characteristics of the sewage. Each of the two filters is 125 ft. in diameter and 3 ft. deep. The filters are designed to treat a normal loading of 1.0 lb. of B.O.D. per cu. yd. of stone, exclusive of the B.O.D. in the recirculated flow, and a loading double this amount during the fruit season. The recirculation ratio is 2.5 in the primary filter and 1.7 in the secondary filter.

Oliver (448) describes experiments on the operation of three 80-ft. trickling filters, each 4 ft. deep. Various mixtures of primary settling tank effluent and humus tank effluent were applied at rates that varied from 269 to 480 g.p.d. (U. S.) per cu. yd. In general, the ratio of primary tank effluent to humus tank effluent varied from 1:1 to 1:1.36. At night during a portion of the test period the rate of application of effluent to the filters was reduced and at other times only humus tank effluent was applied. The operating results from September, 1947, to December, 1948, were as follows:

Test Period	Filter Dosage (g.p.d./cu. yd.)[1]	Filter Influent (p.p.m.)		Filter Effluent (p.p.m.)[2]	
		5-day B.O.D.	Oxygen Absorbed	5-day B.O.D.	Oxygen Absorbed
Sept., 1947, to Mar., 1948	269	91.5	20.7	17.6	6.6
Mar., 1948, to June, 1948	316	—	23.3	13.4	8.7
June, 1948, to Oct., 1948	480[3]	—	25.4	—	8.2
Oct., 1948, to Dec., 1948:					
8 A.M. to 8 P.M.	480	—	23.3	8.8	7.5
8 P.M. to 8 A.M.	319	—	24.8	—	7.3

[1] U. S. gallons.
[2] After 1-hr. settling.
[3] Rate during 16 hr. daily; calculated rate per 24 hr., 266.

Several experiments relating to the operation of trickling filters were conducted under the direction of the Water Pollution Research Board (635). The effect of the periodicity of dosing settled sewage by alternating double filtration on the efficiency of the process was investigated. Settled sewage was applied to two groups of filters by 4-arm distributors. In the first group the distributors rotated at a constant rate of one revolution in 8 min., and in the second group the rate was one revolution from about 1 to 4 min. The average rate of application of the sewage to the filter medium was approximately 180 g.p.d. per cu. yd. No appreciable difference was observed in the character of the effluent from the two groups of filters.

The comparative efficiency of (a) double filtration without alteration, (b) alternating double filtration, and (c) single filtration with recirculation of the effluent was studied. The rate of filtration in all cases was 288 g.p.d. per cu. yd. Alternating double filtration, in general, produced a better effluent than the other two high-rate processes. With regard to surface growths, the alternating double filters and the filters in which the effluent was recirculated remained in better condition than single filters or double filters without alternation.

Settled sewage was applied using single filtration at rates varying from 120 to 1,200 g.p.d. per cu. yd. When the applied sewage had a B.O.D. varying from 150 to 170 p.p.m., the B.O.D. of the settled filter effluent varied from 20 p.p.m. when the rate of application was 120 g.p.d. per cu. yd., to 54 p.p.m.

when the rate of application was 1,200 g.p.d. per cu. yd. The maximum rate of removal of oxidizable matter was approximately 1.4 lb. of B.O.D. per cubic yard of medium per day.

Experiments were conducted to determine the efficacy of "gammexane" (gamma hexachlorocyclohexane) in controlling *Psychoda* flies on trickling filters. One application of 8 lb. per acre of the powder containing 6.5 per cent gammexane (approximately 0.5 lb. of the gamma isomer) without interruption in the flow of sewage to the filter was effective in controlling *Psychoda* and *Spaniotoma* for a period of two weeks.

Tomlinson and Jenkins (598) reported the experimental work on the control of trickling filter flies. They found that the application of sufficient DDT and gammexane to kill 90 per cent of the larvae of *Psychoda* and *Anisopus* had no effect on *Lumbricillus* and *Achorutes*. Application of 10 lb. of DDT and 1 lb. of gammexane per acre controlled the emergence of *Psychoda* for periods of 2 and 4 weeks, respectively. The application to sewage of 5 lb. of DDT or 1 lb. of gammexane controlled the emergence of *Psychoda* flies for about 4 weeks. DDT and Gammexane had no effect on the B.O.D. of the effluent or on nitrification, but the effluents discharged from some of the filters at the time of treatment with insecticides were distinctly toxic to fish.

A survey by Thoman (593) shows that 34.3 per cent of the standard trickling filter plants in the U. S. are not equipped with final settling tanks.

Activated Sludge

Keefer and Meisel (337) have used oxidation-reduction potentials to study the ability of activated sludge to remove B.O.D. from settled sewage. Aeration of the sludge before mixing it with sewage improved its adsorbing properties and 6.3 to 65.2 per cent of the 5-day B.O.D. was removed, depending on the length of pre-aeration and the condition of the sludge before aeration was started. Sludges allowed to stand without aeration quickly lost their ability to remove B.O.D. Further experiments (338) showed that the greatest removal of B.O.D. was obtained with activated sludge containing 500 p.p.m. suspended solids.

Using manometric methods, the effect of shock doses of various chemicals on the oxygen uptake by activated sludge has been studied by Dawson and Jenkins (190). Many inorganic substances act as toxicants when single doses of 1 to 100 p.p.m. of the metallic ion are added. Zinc, copper, chromium, cadmium, and nickel were found to be among the most toxic substances. Generally, the effect is immediate and persistent and is indicated by a reduction in the rate of oxygen uptake. Most organic substances increased the oxygen uptake of activated sludge. With nitrogenous compounds, all amino acids were oxidizable and the higher the nitrogen content, the lower was the increase in oxygen uptake. A time lag of 10 to 30 min. occurred with most of the amino acids used.

Investigations on the mass transfer of oxygen from solution to the microorganisms in industrial fermentations will help to explain the mechanics of aeration in the activated sludge process. Hixon and Gaden (300) have developed equations for each step in the transfer of oxygen by aeration during submerged fermentation and have substantiated them by experiments. Bartholomew *et al.* (106) have proposed a theory of oxygen absorption by suspended mycelia in aerated nutrient broth. Air supply and agitation rate affect the oxygen transfer resistances in various ways and determine the local oxygen concentration at the cells.

Because of the time required to make the tests for sludge index and because the result is affected by consolidation of the sludge, Finch and

Ives (227) suggest as a "sludge settleability index" the ratio

$$\frac{\text{Sludge settled in 6 min. (\%)}}{\text{Susp. sol. (g. per 100 ml.)}}$$

to eliminate the effect of consolidation. The time element may be reduced by plotting the per cent solids against time and determining the tangent of the angle formed by the free-falling portion of the curve and the vertical.

Horasawa has presented the results of his studies on the biology of activated sludge in a series of papers. He (309) confirms the view that the formation of activated sludge is caused by the growth of zooglea and not by physico-chemical flocculation. He recognized three stages in the development of activated sludge, based on the types of protozoa. The protozoa are mainly sessile forms and those creeping on the surface of other substances (311). He (310) also pointed out the effect of temperature on the biological population. The number of types of organisms was lowest in winter and highest in summer, but the number of individuals decreased in summer and increased in winter. When sludge (312) is aerated at very high rates, it disintegrates with a large increase in the numbers of amoebae.

Valuable information has been published on air diffusion media. Anderson (17) has presented a comprehensive report on the large-scale tests made at the Southwest plant in Chicago. As to air economy, he found that there seems to be no difference in diffuser plates with permeabilities between 40 and 120 and that air economy increases after service of about a year. The life of a diffuser plate is determined by the total amount of air passed and is inversely proportional to the amount of dust in the air. The clogging rate is probably inversely proportional to the permeability rating.

The clogging at Chicago seemed caused mainly by dirty air. Wirts (653) pointed out that surface clogging at the liquid side is important at Cleveland. Only 3,500,000 to 4,000,000 cu. ft. of relatively clean air per plate can be passed before the head loss becomes excessive. He believes, therefore, that the life of diffusers also depends on the characteristics of the aeration tank liquor.

At Columbus, Ohio, the clogged diffuser plates were replaced in 1948 by Saran-wrapped tubes. Blodgett (116) reported that early clogging of the tubes resulted from the sand which had been used to fill the old concrete plate holders. The tubes were restored to their original permeability by soaking in a detergent and washing with a high-pressure water jet. The pressure gradually increased during the next six months. When the increase amounted to 0.75 p.s.i., the tubes were raised and washed in place with a high-pressure water jet. This jetting in place reduces the pressure as much as 0.5 p.s.i. and it is estimated that removal, soaking, and jetting will be required every two or three years. The cost of jetting in place is about 2¢ a tube. Removal, soaking and jetting will cost about 10¢ per tube.

Samson (532) found that diffuser plates, clogged mainly with mineral oil from the air compressors, could be cleaned by distillation of the oil in a homemade apparatus consisting of two oil drums and a gas burner. Backmeyer (98) cleaned ceramic tubes by washing in detergent and soaking in chromic-sulfuric acid, followed by a thorough rinsing.

Two-stage activated sludge has been used at Chula Vista, Calif. According to Wright (659), the Process Oxidators contain a central aeration compartment and a settling unit in the annular outer section. Solids settling in the outer compartments are raked to the center for removal or recirculation. Preliminary tests showed that two units, in series, produced an effluent containing 60 p.p.m. of suspended solids, or a removal of 80 per cent. When 30 p.p.m. of ferric chloride were

added, 91.3 per cent of the suspended solids were removed.

Brown (134) has described the new Maple Lodge activated sludge plant for the Colne Valley area, Hertfordshire, England, which was to go into operation at the end of 1950. Eight aeration units, one of which can be used for reactivation, will provide 12-hr. aeration for 12 m.g.d. (Imp.). The ridge and furrow arrangement of diffusers, which appeared slightly more efficient than the spiral flow system at the West Middlesex works, will be used. New dome-type diffusers will be installed in three units. Because the plant effluent eventually reaches the Thames River above the intake of the Metropolitan Water Board, the Board requires that the entire plant effluent comply with the Royal Commission Standard of 20 p.p.m. for B.O.D. and 30 p.p.m. for suspended solids. This is a much higher standard than that of the Ministry of Health, which requires full treatment for flows up to three times the dry weather flow, partial treatment for flows between three and six times the D.W.F., and no treatment for flows exceeding six times the D.W.F. Rankin (495), in his discussion of the paper, pointed out that when the design values, such as per cent return sludge, aeration periods, and settling periods, are put on a per capita basis, many of the differences between British and American practice tend to disappear.

Recirculation of the final effluent in a small institutional activated sludge plant eliminated odors caused by septic sewage, improved the appearance of the final tanks, and helped produce a better activated sludge, according to Hillis (299).

Imhoff (324) has compared the data from four New York City step aeration plants with several conventionally operated American activated sludge plants and pointed out the advantages of step aeration.

In order to increase the capacity of the Wards Island (New York City) plant, structural changes have been made in the final settling tanks and step aeration has been provided. According to Gould (265), the sewage may now be added at the beginning and at one-fourth and three-fourths of the way through the aerators. It is expected that the changes will make the plant much more flexible and will raise the dependable capacity of the plant from 180 to 240 m.g.d. The cost of the alterations was $260,000 for the final tank changes and $134,000 for step aeration.

Synthetic detergents seemed to be the cause of violent foaming at one of the Batavia, Ill. (79), mechanically aerated plants. The foaming, which continued several months, resulted in a deterioration of the effluent and of the settling qualities of the sludge.

It is interesting to note that a small activated sludge plant of the Haworth type was built in Poland (115) to serve a sanatorium.

As a result of operating experience during the past five years, Griffith (273) believes that the efficiency of contact aeration treatment depends on the total amount of biological film, the effective passage distance which each sewage particle must take in its helical path through the aeration tank, and the treatability of the sewage.

The results obtained from recirculation to the activated sludge plant of nitrified effluents obtained by filtration of effluent from the activated sludge plant are reported by Edmondson and Goodrich (216). Factors inducing higher nitrate production in the nitrifying filters were studied. Nitrified effluents from the special nitrifying filters were also recirculated to the regular filters for the relief of ponding. The capacity of the filters was thus increased two- to three-fold.

Pasveer (461) indicates that the oxygenation of water in a tank equipped with rotary brushes takes place entirely in the close vicinity of the brushes and particularly in the

mass of foam thrown up. The quantity of oxygen per kilowatt-hour introduced into the water is, therefore, greater in smaller tanks. The effect can be intensified further by placing a baffle in the path of the brush to force the mass of foam to change direction.

Experiments conducted by Edmondson and Goodrich (216) to increase the efficiency of aeration of Sheffield paddles revealed that shallow immersion increases the efficiency, increased speed of rotation increases the oxygen input, and increased depth of aerator increases the velocity in the aeration channels. The solution of oxygen with this type of aerator is primarily due to film formation and spray playing in the atmosphere above the top water level in the channels. Best results are obtained when the speed of rotation is 30 r.p.m. The highest efficiency was obtained with triangular blades.

Chlorination

The essential public health need for chlorine is now widely recognized. Based on 1945 survey data, chlorination is utilized as a part of the treatment process in more than 1,200 U. S. sewage plants, and the practice is more general as the size of the community increases (594). The newer and more rigid requirements of stream pollution abatement programs will generally increase the requirement for chlorine. There is a continuing development of chlorination methods in the treatment of industrial wastes.

Provisions to assure the availability of chlorine for sanitation needs in the coming year were predicted in announcement of a chlorine "cutback" order being formulated by the Chemicals Division of the National Production Authority (22) late in 1950. (The order (87), M-31, dated January 23, 1951, requires suppliers to furnish chlorine for sewage treatment during 1951 at a rate equivalent to the 1950 use.)

Research

Studies of the chlorine demand constants of Detroit's water supply have led to the development of a formula which makes it possible, on the basis of preliminary determinations, to predict the amount of chlorine required to maintain specific residuals in the finished water (226). A study has also been made of the nature of chlorine-consuming substances present in the water (588). Results of these studies, although applying to water having a relatively low chlorine demand, should be of interest in sewage chlorination research.

Reports are available of several British investigations relating to chemical and bacteriological aspects of chlorination: new analytical procedure was developed to study the formation and decomposition of the chloro-substituents of ammonia in water (453); a study was made of the bactericidal activity which obtains during the formation of chloramines (314); and a review was provided of the factors and the mechanism determining the efficiency of chlorine as a disinfectant (9).

Large concentrations of chloramine-T are required to be bactericidally equivalent to hypochlorites. This is evident in a study by Weber (636) of the effect of concentration and pH reaction on the germicidal activity of chloramine-T. However, for use with certain resins, the high reactivity of chlorine may be a disadvantage (129).

Nagano (437) considers that, in the chlorination of sewage, sulfide is changed to sulfate rather than to sulfur. Results are reported showing that the theoretical ratio of 8.87 to 1 (chlorine to sulfide) is always exceeded in chlorination of sewage at the Hyperion plant of Los Angeles. While a part of the chlorine demand is recognized as due to organic matter, laboratory studies are cited as evidence that verifies the theoretical ratio.

A comprehensive summary of the

literature concerning the toxicity of industrial wastes to fish has been provided by Doudoroff and Katz (204); chlorine and cyanogen chloride are included in their review. Although the actual values vary with a number of conditions, free chlorine or hypochlorous acid is demonstrated to be extremely toxic to fish. Cyanogen chloride appears to be even more toxic.

Disinfection

As a guide to chlorine dosage requirements in sewage disinfection, Eliassen and Krieger (219) have presented graphically the relationships of most probable coliform numbers, residuals, and contact time requirements. Their study was based on variations of chlorine dosages of 100, 133, 167, and 200 per cent of the chlorine demand, on the standard chlorine demand test, on ortho-tolidine measurements of residual chlorine, and on the use of statistical methods for analyzing results.

Laboratory investigations by Heukelekian and Smith (293) demonstrated that stipulated residual coliform organisms cannot be predicated on the basis of chlorine dosage. Among the specific factors evaluated in their study, the following are particularly useful: To achieve stipulated numbers of residual coliform organisms in settled sewage with a 30-min. contact time requires an amount of chlorine less than half of that required with a 5-min. contact time. Nearly the same amount of chlorine is required to achieve given counts of residual coliforms in activated sludge and trickling filter effluents; but the amount is lower than that required in settled sewage. A greater amount of chlorine is required to achieve a stipulated residual coliform organism count when chlorine solution has a concentration of 5,000 p.p.m. than when the concentration is 200 to 1,000 p.p.m. of chlorine.

British investigators (12) have also determined that the bactericidal action of chlorine depends both upon the proportion of the chlorine demand satisfied and upon the absolute size of the dose applied. They consider the effectiveness of chlorination should be judged not only by the percentage of bacterial kill accomplished, but also by the interval elapsing before after-growths become appreciable.

During the past three years, subresidual chlorination has been employed at the Hyperion plant of Los Angeles (109). Analyses of data on bacterial kill indicate disinfection can be obtained with less chlorine than is required to produce a residual with ortho-tolidine. Indicated reduction of coliform organisms resulting from approximately 80 per cent satisfaction of the chlorine demand of the sewage is: for 110 samples, more than 98 per cent; for 12 samples, 80 to 98 per cent; and for 10 samples, lesser percentages.

In order to provide chlorine contact tanks of safe design, studies were made for the New Hampshire Water Pollution Commission (239). Curves are presented to compare the coliform numbers found and the detention time used, and to relate these factors to the chlorine dosage applied. Results are illustrated in a summarized chart.

The applicability of chlorination to the disinfection of sludge solids, as a means of permitting the disposal of solids directly to receiving waters, has been investigated by Tyler *et al.* (605). Adequate pre-chlorination is found effective, although raw and digested solids can be directly chlorinated by providing thorough mixing. Pre-chlorination is the preferred method as it improves the settling characteristics of the sludge.

Pathogenic organisms in the wastes discharged from duck farms are potentially dangerous to man; such organisms have been recovered in shellfish taken from polluted waters (113). The elimination of this pollution by sedimentation and chlorination appears possible; the chlorine demand of the waters is about 10 p.p.m.

Applications

A survey (563) of the bacterial quality of the waters overlying shellfish areas in and near Hampton Roads, Va., was made in 1949–1950. Three sewage treatment plants provide primary settling and chlorination; data have been reported to indicate the efficiency of chlorination, and the important factors are found to be plant design, flow, and detention characteristics. Careful plant operation is essential to maintain a satisfactorily low bacterial density.

A report for the fiscal year 1949 shows the chlorine requirement for sewage treatment of the City of Detroit to be 2,617 tons (34). Seasonal variations were from a maximum of 344 tons per month (August) to a minimum of 145 tons per month (April).

At Carbondale, Ill., the use of chlorination in conjunction with operation of the activated sludge process has made it possible to handle an industrial waste load without plant enlargement (89). Chlorination of return activated sludge proved an effective corrective for sludge bulking, which impaired the effluent quality.

The Bronx-Hutchinson-South Yonkers plant plays a major role in treatment of Westchester County (N. Y.) sewage (443). Originally planned and operated with chlorine supplied in ton containers, the change to single-unit tank cars at this plant resulted in considerable saving. Two one-ton containers are in use to provide an uninterrupted chlorine supply during changing of tank cars.

Simple modifications of a light utility truck have been described (405) for adapting it to handle ton containers of chlorine. Although two men usually perform the operation, one man is able to carry out loading or unloading with no heavy lift or pull being required.

Design of the new sewage treatment plant for Cincinnati, Ohio, includes three chlorination units: with one as a stand-by, the maximum potential dosage will be 20 p.p.m. for 150 per cent of the average flow (597). Proposed treatment for the sewage of Tacoma, Wash., includes modified primary treatment with chlorination of both sludge and effluent. The chlorinated sludge would be discharged about 2,500 ft. from shore at a depth of 200 ft. (547).

Industrial Waste Treatment

In discussing treatment of industrial wastes in municipal sewage plants, Hess (290) cites data illustrating the fact that the chlorine demand of both industrial waste and sewage may be lowered when mixed together. Unfortunately, details of the proportions and procedure involved in obtaining these data are not given; as a result, the interpretation is not clear when it is stated that "the presence of sewage reduced the chlorine demand of all the industrial wastes and that in one case the industrial waste reduced the chlorine demand of the sewage.

Pearson and Sawyer (466) have described a chlorination and sedimentation method for treatment of process waste water in the manufacture of beet sugar. The chlorine requirement is reported to range from 25 to 60 p.p.m. Use of this method at two mills has demonstrated the treated process water can be re-used, and thereby be eliminated as a stream pollutant. Approximately two tons of sugar per day can be recovered in a 1,000-ton plant, and water requirements for operation of the diffusion battery are reduced by one-third.

A report on operation of the hypochlorite process for treatment of wool scouring wastes has been made by Cameron (157). Elimination of solids, removal of 70 to 75 per cent of the B.O.D., and prevention of odors by the treatment are reported to have solved the stream pollution problem at this mill.

Wastes from small abattoirs can be simply and effectively treated by a batch method reported by Stiemke (572). Mixing, flocculation, and sedimentation are done in one tank. Hog processing wastes showed 95 per cent reduction, using applications of 0.2 lb. available chlorine (as calcium hypochlorite or chlorinated lime) and 3 to 5 lb. of alum per 1,000 gal. of waste. The cost of chemicals is given as 7.5¢ to 12.5¢ per hog unit.

The treatment of industrial wastes containing cyanides by chlorination under alkaline conditions has been widely investigated, and the method is employed at a large number of plants. The technical literature has provided research reports and operating details concerning this method. In a critical review of the literature on disposal of plating wastes (201), oxidation of cyanide to less toxic cyanate by chlorine is considered the most satisfactory and cheapest procedure. The usual practice is to destroy the cyanate by an excess of chlorine. Cyanide wastes containing silver cannot be so treated, as recovery of silver is rendered difficult. Details of plant design, equipment, and chemical requirements for continuous flow-through chlorination to oxidize cyanides to cyanates have been reported (26). These are based on small (300 g.p.h.) and large (6,000 g.p.h.) flows of wastes containing cyanides.

Batch treatment of plating wastes is employed at the Norristown, Pa., plant of the American Screw Co. (556). Liquid chlorine and caustic soda are the treatment chemicals. The equipment operation, and cost data of this plant are described; estimated cost of operation, for chemicals and power, is $17 per month. Continuous treatment of plating wastes is employed at a plant in Lockland, Ohio (498). Chlorination and the addition of caustic soda is employed to completely oxidize cyanides to carbon dioxide and nitrogen. Cost data and chemical analyses indicate reclamation of the treated effluent will be economical and safe; planning is in progress to that end. Industrial wastes which contain cyanides usually provide a diversity of other constituents requiring treatment. The study of these wastes, and the design of treatment plants, has been described by Tarman and Priester (590). In each of the several plants discussed, chlorination is employed for oxidation of cyanides.

In a review of methods for treatment of cyanide wastes, the Michigan Water Resources Commission found 49 per cent of the definitely determined instances of fish mortality to be traceable to cyanides (179). Disposal and treatment methods for these wastes were reviewed, and chlor-alkali oxidation was considered of widest applicability. British investigators have reported studies of the reactions involved in the chlorination of wastes containing cyanides. Cyanogen chloride, produced as an intermediate product, is reported to hydrolyze at a rate dependent upon the form of chlorine; about 125 min. is required in the absence of hypochlorite, or 15.5 min. in the presence of 10 p.p.m. available chlorine, both at pH 11.0 (215). The reactions of sodium and calcium hypochlorite upon cyanides at controlled pH values were studied, and a process was developed for treating waste waters containing cyanide (213). The process is reported applicable to liquids containing many simple and complex cyanides.

Chlorine Products

An organic chlorine disinfectant having low reactivity toward organic matter has been successfully employed to control growths of slime bacteria in resinous zeolite water softening units. The trade name of the material is "Sterimine" (25).

Development of an organic chlorine compound, as a commercial sanitizing agent, has been described (28). The material, termed "Antibac," is en-

tirely soluble and releases up to 1,600 p.p.m. of available chlorine.

The spray application of Cloroben in sewer manholes has been found capable of keeping the roach population under good control. Details of this practice at Houma, La., have been described (246).

Other Disinfectants

The bactericidal efficiency of quaternary ammonium compounds has been investigated by Butterfield, Wattie, and Chambers (151). These materials are developing as commercial sanitizing agents, but are not suitable for large-scale disinfection.

Ozone is frequently discussed in foreign technical literature and comparisons have been made between ozone and chlorine for water supply disinfection (140) (373). The French and American conceptions of ozonation of drinking waters have been described and the two techniques have been compared (238). The bactericidal action of ozone has also been extensively reviewed in a publication of the Argentine Chemical Association (372).

Sludge Digestion

Theory and Mechanism

An extensive study of the isolation of pure cultures of anaerobic, mesophilic cellulolytic bacteria from sewage sludge was reported by Hungate (319). No cellulose digesting organisms were isolated from the raw sludge; however, bacterial counts of 880 per ml. and 2,600 per ml. were obtained from the first- and second-stage digesters at the Moscow, Idaho, sewage treatment plant. There appears to be a marked prevalence of non-spore-forming, obligately anaerobic bacteria among the cellulolytic strains isolated from digesting sludge.

A comparative study of the available culture of thermophilic cellulose fermenting bacteria by McBee (397), indicated that it is possible to obtain and cultivate pure cultures of these organisms. The end products of cellulose fermentation were the same for all of the cultures examined, varying only in amounts of each produced, and in the recovery of cellulose.

The possibility of production of petroleum from the anaerobic digestion of waste organic materials by *B. perfringens* is reported by Laigret (362).

Toxic Effects

Pagano, Teweles, and Buswell (452) reviewed the conflicting information in the literature with respect to the toxic effect of chromium compounds on aerobic and anaerobic stabilization processes. Studies were conducted in the laboratory on the effect of different and varying amounts of chromium compounds on the methane fermentation of acetic acid. Hexavalent chromium was found to have a greater toxicity than trivalent chromium and concentrations of 1.5 p.p.m. caused a decrease in the rate of fermentation after 3 to 5 doses had been applied.

Abelson and Aldous (3) and MacLeod and Snell (392) reported the toxicity of nickel, cadmium, cobalt, zinc, and manganese to *Escherichia coli*, *Aerobacter aerogenes*, and other organisms, to be markedly reduced by the presence of considerable amounts of magnesium. This may be a factor to be considered in the evaluation of the various levels of toxicity of metals reported by workers in the different sections of the country.

Operation

The operational difficulties associated with scum formation and foaming were discussed by Haseltine (280). A general analysis of the causes of common digester upsets and the corrective measures employed to overcome such difficulties was presented.

Hillis (298) reported on the 9-year accumulation of a scum layer in a floating-cover-type digester the necessitated draining and opening the tank in order to break up the scum. The scum layer greatly reduced the effec-

tive capacity of the tank for digestion.

In an operator's forum, Van Kleeck (619) led a discussion on the relative merits and demerits of liming digesters. Differing opinions were reported on the value of lime in controlling digester operation.

Weibel, Straub, and Thoman (637) (638) reported the results of a very comprehensive study of household septic tanks and disposal systems. A review of the technical literature and of existing regulations and practices regarding the use and control of domestic septic tank systems was presented. Extensive experimental studies were made, both in the laboratory and in the field, in an attempt to ascertain the most efficient design of a septic tank with respect to size, shape, compartmentation, and freedom from operating difficulties. Data were reported on the efficiency of septic tanks as settling tanks, sludge digesters, and sludge storage compartments. A somewhat general conclusion derived from their study is that the most efficient household septic tank is one of oval, rectangular, or circular shape possessing some form of compartmentation, and a minimum capacity of 500 gal.

Design and Construction

A review of the construction of sludge digesters was reported by Flood (234) with respect to operational difficulties resulting from improper design and construction. The greatest single difficulty experienced with the operation of sludge digestion tanks has been in the accumulation of masses of relatively inert scum, which renders ineffective a substantial proportion of the tank capacity and clogs supernatant and overflow pipes. Satisfactory control of scum formation involves breaking the scum by mechanical agitation with paddles or rotors, or by adequate mixing and circulation with directional control of the incoming sludge.

Floating covers for the sludge digester at the new Portland, Ore., sewage treatment plant (45) incorporate a deviation from existing designs in that the cover, in its down or empty position, is supported by four concrete piers at the center. The principal advantages claimed are a significant reduction in the size of the supporting truss work of the cover and simplification of cover erection, thus resulting in construction economies.

The construction and operation of an experimental pilot plant for the heated digestion of sludge from the Aldwarke sewage works of the County Borough of Rotherham was reported by Finch (228). The sludge consists of primary and activated sludge and percolating filter humus, in addition to considerable trade wastes. Pilot plant results indicated a digestion period of about 26 days at 80° to 85° F. to be ample for one-stage digestion. The digester capacity should be about 2.5 cu. ft. per capita. A gas yield of 1.2 cu. ft. per capita with a calorific value of 650 B.t.u. per cu. ft. might be expected under these conditions.

Heating

A panel discussion led by Symons (585) reviewed the heating of sludge digesters and related problems. Considerable attention was given to such items as optimum temperature for digestion, the relative merit of internal heating as compared to external digester heating, and corrosion of digester equipment. A great deal of practical experience related to the heating of digesters was presented in the discussion.

Gas Utilization

Should engines operating on sewage sludge gas be 2-cycle or 4-cycle, supercharged or non-supercharged, or be designed as spark ignition or dual-fuel engines? A discussion of these aspects in the selection of a sewage gas engine was presented by Hayes (284). Supercharged engines appear

to possess a lower cost per horsepower in large engine sizes, better operating economy, and longer engine life. The choice between spark ignition and dual-fuel engines is primarily based on the amount of sludge gas, an abundance of gas favoring the low-compression spark ignition engine.

The Columbus, Ohio, sewage treatment plant (20) has recently installed a 1,440-hp. dual-fuel engine to operate on from 10 per cent oil and 90 per cent sludge gas to 100 per cent oil. Increasing favor for the use of dual-fuel engines is further indicated by the installation of 9 supercharged dual-fuel engines at the Los Angeles Hyperion Beach sewage treatment plant. The engine cooling waters will be used to heat the digesters by direct steam injection.

Wissmiller (654) discussed the use of spherical pressure vessels for sewage gas holders. Spherical pressure vessels are available in a wide range of diameters and pressure, the largest built to date having an inside diameter of 76 ft. 3⅜ in. The maximum allowable working pressures may be anywhere from 30 p.s.i. to 100 p.s.i. or more.

Buckner (137) discussed the factors influencing sewage sludge collection and preferred steel tank collectors.

Effects of Industrial Wastes

Vrooman and Ehle (630) reported the results of a pilot plant study on the digestion of combined tannery and sewage sludge. Successful digestion of the combined tannery and sewage sludge points the way to a satisfactory solution of a serious industrial waste problem for the city of Gloversville, N. Y. The waste problem contributed by tannery wastes is approximately 4⅔ times that contributed by the domestic wastes of the city.

A review of the factors involved in "high-rate anaerobic digestion" or methane fermentation was reported by Gehm and Behn (251). A list of general criteria for the evaluation and comparison of high-rate anaerobic digestion studies is suggested. High B.O.D. reductions were reported for anaerobic digester loadings of 0.04 lb. of B.O.D. per cu. ft. per day.

Anaerobic fermentation plants for the reduction of B.O.D. of concentrated organic wastes are capable of continuous operation for indefinite periods according to Buswell (147) (148). Loadings of 0.14 lb. of B.O.D. per cu. ft. of digester volume per day have been found feasible in many pilot plant studies. Existing plants loaded at 0.10 lb. B.O.D. per cu. ft. per day regularly produce a 70 to 80 per cent improvement in the quality of the waste. Although the anaerobic process is economical, two limitations are its inability to produce an effluent comparable to that yielded by aerobic treatment and the cost of anaerobic treatment increases as the concentration of the waste decreases.

Sludge Disposal and Utilization

Concentration, Dewatering, and Vacuum Filtration

Zack (661), in a review of sludge dewatering and disposal methods, points out the reduction in digestion capacity possible, the increase in vacuum filter rates, and the reduction in sludge volume afforded in sea barging operations by the concentration of sludge in tanks. The quantities of sludge removed from sedimentation tanks and digestion tanks are presented. In addition to a lower volatile content, digestion reduces sludge volumes from 35 to 50 per cent.

Zack (661) also summarizes in tables vacuum filter operation at the larger plants. Ferric chloride, with or without lime, continues to be the most commonly used sludge coagulant. Richter (506) points out that the so-called package-type filter has reduced operating attention and lowered initial cost of vacuum filters for smaller communities. Communities of 7,000 or more persons, he feels, can economically use them. Cord filters, he finds,

give better performance than cloth filters, except when the latter has just been provided with a new cloth.

Genter (254) discusses elutriation as a means of dewatering sludge. Chemical requirements for various sludges and basic design data for a small plant utilizing elutriation prior to vacuum filtration are given.

Komline (355) discusses the design factors in vacuum filtration of sludge.

Clements, Stephenson, and Regan (171) show that freezing of primary and activated sludge improves the settling and dewatering of sludge with or without chemicals. They point out that the freezing should be complete. The supernatant liquors and filtrates had a low oxygen demand and the filter cake had a solids content of 23 to 30 per cent. The cake production was 350 lb. per sq. ft. per hour for digested sludge and up to 70 lb. for activated sludge. A freezing machine utilizing the latent heat was developed.

Lagooning

Zack (661) reports the continued and extended use of lagoons for disposal of both undigested and digested sludge, even by many large plants, such as Chicago; Houston, Tex.; Indianapolis, Ind.; Rahway, N. J.; Akron, Ohio; Baltimore, Md.; and Dallas, Tex. In most cases, the use of lagoons has resulted in odor complaints and they cannot, therefore, be considered as a suitable permanent means of disposal.

Heat Drying and Incineration

Current practice is summarized by Zack (661). The plant at the Lederle Laboratories, Pearl River, N. J., utilizes a mechanically stoked refuse incinerator for burning rubbish, sewage sludge, and spent media. The sludge discharges to an auxiliary sludge drying hearth.

At Frederick, Md., undigested primary sludge cake is mixed in a ratio of 1 to 10 parts with garbage and rubbish and burned in a regular refuse incinerator.

Utilization and Composting

The pros and cons of this subject provided a major topic of discussion at the Federation's 1949 Operators' Forum (81). Rudolfs, speaking for utilization, believes that in many cases utilization may be less costly than destruction, as well as providing benefits derived from soil building and stimulation of plant growth. When sludge is barged to sea it furnishes fish food and fertilizer for sea plants. With reasonable precautions he finds there should be no health hazard from the use of sludge as fertilizer. Rowen points out that sludge incineration is the most sanitary method of disposal, and that it offers simplification of plant operation and design. It is well to remember, however, that such simplification may be at the expense of the usual benefits from digestion and utilization of sludge.

Foster's (235) summary of sewage sludge use in the United States shows a trend of increasing public interest in sludge for soil conditioning. Income reported by a cross-section of the cities listed follows:

City	Type of Sludge	Price Received, Per Ton
Milwaukee, Wis.	Heat-dried undigested activated	$28 to $30
Phoenix, Ariz.	Air-dried	Up to $6.10
Stamford, Conn.	Heat-dried digested primary	Up to $5.35
New London, Conn.	Vacuum-filtered digested primary (pulverized)	$10.00
Chicago, Ill.	Heat-dried activated	$15.00
Houston, Tex.	Heat-dried raw activated	Up to $17.00

A much needed comprehensive study of processes of composting as practiced in many countries has been prepared by the Sanitary Engineering Department of the University of California (85).

Partridge (460) considers the agricultural utilization of domestic wastes a perfectly admissable method. It cannot be accorded, however, a superiority over incineration. Local conditions will determine the selection between these two methods. The agricultural utilization of domestic wastes in Spain is discussed by Maroto (393); in Italy, by Rodella (513); and in Belgium, by Defourny (192). The experience with "zymothermic" treatment of domestic wastes in Biarritz is discussed by Delord (196). The construction of the cell and the analysis of the final product are given. Bacteriological and parasitological examination did not reveal the presence of any elements injurious to the health of man and animals.

Burke (143) concludes that composting cannot be considered as a general method of refuse or sludge disposal, but rather as a method of converting organic wastes to a form that can be utilized by the farmer. From the standpoint of cost analysis the scheme can be considered a success. Wylie (660) discusses the procedures in composting of different kinds of organic waste. Brunt (136) discusses methods of composting of garbage, and the experience in Baden-Baden with composting of fresh sewage solids and garbage is reported by Straub (575). The fertilizer value of the compost was found equal to or better than manure. Cost analysis shows that the product can be marketed more cheaply than any other fertilizer. Poepel (476) discusses the composting of digested sludge with garbage.

Williams (648) described the Verdier process of garbage fermentation to be completed for Miami, Fla. The plant will be financed by a private company, with the city making an annual payment for disposal service. The plant will be city-owned in 30 years, or an option permits city purchase at the end of 15 years. The plant, with a rated capacity of 900 tons per day, will produce a low-grade commercial fertilizer. The process is said to be odorless and involves shredding of the refuse and charging of the shredded material into closed cells for 18 to 24 days, at the beginning of which ferment liquor from previous batches is sprayed over the fresh material. Temperatures of 160° to 180° F. are reached, which destroys pathogenic organisms. Screening of the treated refuse completes the process. If the process proves nuisance-free and trouble-free, as well as practical, it will be one more method by which valuable organic matter can again be returned to our starved soils.

Sludge Removal

Sperry (569) discussed the advantages of removing sludge cake from the drying beds at Aurora by saddlebag tractors. Such tractors, he finds, are relatively low in cost, easily housed, and have great versatility. They may be used for moving grit and ashes, grading roads, and plowing snow. They travel over soft ground, can climb sludge piles, and one man can operate a machine. The tractors apply a load of only 7 lb. per sq. in. to the sand surface of a sludge bed and no damage to the tile has resulted. The side bins hold 3 cu. yd. of material. In 1949, 2,738 cu. yd. of 5-in. thick sludge cake were removed. The tractor has corrosion-resistant metal bins, easily removed for servicing. The only objectionable feature of the machines appears to be the vibration. This makes an abdominal support for the driver desirable.

Mechanical Equipment

A comprehensive review of the application and operation of mechanical equipment in sewage treatment proc-

esses is presented by Flood (232). The highly developed mechanization of sewage treatment has not been accomplished without attendant problems and difficulties, and these experiences stress the need for clear and specific plans and specifications if the best equipment for a particular service is to be obtained. In this regard, pertinent remarks on what operators want in sewage plants are presented in the transcript of the 1949 Operators' Forum (620). Evans (225) points out the trend for more mechanization of sewage works in England, resulting from increased labor difficulties and costs, and discusses the factors to be considered in the selection of machinery for each of the various unit processes. Brown (134) describes the sewerage and sewage treatment facilities in the Colne Valley area, Hertfordshire, England. The Maple Lodge sewage treatment plant is equipped with three 36-in. comminutors, Meider-type scrapers for sludge removal in rectangular primary tanks, longitudinal ridge and furrow arrangement of diffusers in the aeration tanks, and circular final settling tanks of upward flow design equipped with ring-type scrapers. All pumping, air compressing, and other mechanical units will be electrically operated and all electric power will be generated at the plant. Power units are 6-cylinder vertical diesel engines direct-coupled to 750-kva. alternators. The engines are of dual-fuel type and are rated at 660 hp., but when supercharged will develop 950 hp. Power for operating all pumping stations will be generated at the works by 6 units and transmitted by underground high-tension cables. Primary sludge only will be digested for gas production. Sludge disposal equipment consisting of vacuum filters, flash dryers, and an incinerator is provided. Flexibility of operation is provided so that digested sludge and surplus activated sludge may be disposed of as fertilizer or incinerated. Extensive instrumentation is used throughout the plant and works with central control at the plant.

Kennison (342) describes equipment as designed and installed for the Nut Island treatment plant in Boston, Mass. Material collected on medium racks will be sluiced to comminutors. Dual-fuel engines for power purposes will run on digester gas and oil in any proportions from 95 per cent gas and 5 per cent oil to 100 per cent oil.

The increased interest in dual-fuel engines as evidenced by the two major installations noted above is given further consideration by Hayes (284), who discusses the questions of dual-fuel engines *vs.* spark ignition systems; 2-cycle *vs.* 4-cycle; and supercharged *vs.* non-supercharged engines. If there is a large surplus of gas, a low-compression spark ignition engine is advisable. If there is a large deficiency of gas (more than 10 per cent), a dual-fuel engine is preferred because diesel fuel is cheaper and more readily handled as stand-by fuel than either propane or butane. Both 2-cycle and 4-cycle engines are operating successfully. Choice between the two should depend primarily on cost and specific engine details. Supercharging has the advantage, in large engine sizes, of lower cost per horsepower, better operating economy, and no harmful effects with respect to engine life. Polakov (477) discusses details involved in selection, application, and design of dual-fuel engines. Haseltine (279) discusses the use of a gas engine-pump combination equipped with controls so that as long as sufficient gas is available the speed of the engine can be automatically varied with the liquid level in the wet well. Problems of design and economies of power generation at the Butler, Pa., plant are reviewed.

Behn (111) investigated rotary vacuum filtration, pressure filtration, and two-stage vacuum filtration for use in mechanical dewatering of waste sludges at integrated pulp and paper mills, a bond mill, a tissue mill, and a fibre

mill, and concluded that rotary vacuum filtration should be feasible for the first type. Pressure filtration and two-stage vacuum filtration are worthy of consideration at mills, especially where alum coagulation is anticipated as a waste treatment measure. Ehemann *et al.* (217) found that the OCO water system, which uses a pressure-type plate and frame filter, offers a practical solution to the recovery of industrial process water from paper mill white water, and that the filtered water has proved to be satisfactory for use on low-volume high-pressure showers to clean felts and wires.

Kline (350) describes an automatic sampler in which compressed air is used to lift a 30-oz. sample, one-third of which is discharged to one of a series of containers arranged to collect 1-hr. composites over a 24-hr. period. Gray *et al.* (269) and Richmond (505) describe other automatic sampling equipment.

Trouble-shooting electrical equipment and controls, and the proper selection and installation of electrical equipment with regard to location in the sewage treatment plant are discussed by Greiff *et al.* (272).

Glazebrook (257) describes the background and development of trash pumps which led to the invention of the new single-channel bladeless sewage pump. The characteristics and performance of the pump are presented. Lindeman (379) reviews design features of non-clog pumps.

Gibbs (255)(256) describes a flotation unit for the treatment of soap manufacturing waste waters. Development of equipment to introduce large volumes of small air bubbles to a portion of the flow is discussed. Air is introduced into the system at 5.5 c.f.m. under a 13-in. (Hg) vacuum and released in a flotation unit. Lime is used as an aid. Removal of undissolved fatty acids exceeds 96 per cent. The scum removed contains approximately 18 per cent dry solids. Details of equipment are not given, nor are operating costs, but it is stated that the net value of the recovered sludge is enough to pay operation costs and amortization of capital investment. Ashley (93) discusses the application of the Bulkley-Dunton Colloidair separator to the treatment of waste from train washing, tank car washing, and roundhouse and shop operations and reports 100 per cent oil removal.

Couch and Kulin (182) discuss the widely publicized garbage disposal by household grinders at Jasper, Ind. Comparative data are given on the effectiveness of five units investigated. Bid prices on grinders varied from $35.19 to $52.70. Unit cost of $74.17 for complete installation was obtained. Sewage treatment plant capacity has been increased by 50 per cent, digestion capacity by 70 per cent, and sludge drying by 60 per cent. No change in the primary and secondary tanks was made. Cosens (181) estimates the use of grinders will increase water consumption 2 to 3 per cent, primary sludge about 75 per cent, and B.O.D. loads on secondary processes 10 to 20 per cent.

Prager's (483) interesting article tracing the development of sludge blanket clarifiers led to additional comments by Paterson (462) and Bolger (121) on the age and evolution of the art. Nichols (443) describes the installation of an air-operated chlorinator handling up to 3,000 lb. daily and using 16-ton tank cars as supply.

Anderson (17) presents a well-documented study on air diffusers conducted by the Sanitary District of Chicago. Plates of different permeability, porous tubes, and slotted brass pipes, with various arrangements of spacing, were included in the diffuser setups studied. As a result of the study, the diffuser system design for one battery at the West-Southwest works used improved air filtering methods and 80-permeability diffusers arranged in 6-plate precast concrete holders placed normal to the tank walls. The concentration of diffuser

plates is 27 per cent greater in the influent than in the effluent half of the tanks. Blodgett (116) discusses experiences with Saran-wrapped tubes for air diffusion and prefers their use to plates.

Reilly (500) describes a hydraulically operated trencher on a rubber tired tractor. Lordley (382) describes a mobile lightweight service trencher. Sperry (569) gives design details for a hopper attachment to a tractor for use in moving sludge.

Szniolis' article on a complete sewerage system cleansed by evacuation by periodic application of air vacuum has been translated by Straub (586).

Reclamation, Irrigation, Percolation, and Lagooning

Various aspects of controlled reclamation of water from sewage and industrial wastes for augmenting underground water resources in Los Angeles County are discussed by Rawn (497), Ludwig (385), and Hedger (287). The ground-water supply constitutes the major source. Also, due to increase in population and industry the ground-water table has been lowered, accompanied by salt water infiltration along the coastal area. A sewage reclamation plant differs in essence from one built for disposal purposes. Basically, domestic sewage is suitable for reclamation purposes. Wastes with high mineral content must be segregated. The effluent from a water reclamation plant will have to be spread on percolation beds or spreading grounds. Tests with trickling filter effluent indicated an average percolation rate of 1.0 acre-ft. per acre per day and the absence of pollution. Nothing short of an oxidized secondary effluent should be applied to spreading areas.

The effluent from the Fresno, Calif., primary treatment plant is irrigated on land and used for raising grass for cattle use, according to Segel (550). The farm has shown an operating profit.

A general discussion of pollution of irrigation water in western states was presented by Wright (658), who calls attention to the need for uniform requirements for the use of polluted irrigation standards, based on health hazards involved from epidemiological studies.

Cecil (164) suggests the disposal of certain chemical wastes into underground formations, similar to the practice with oil field brines. Billings (114) calls attention to the dangers of such a practice when the wastes contain materials which may impair the quality of the underground waters, and to other considerations dealing with the character of the soil and the hydraulics of underground water movement.

From the standpoint of disposal of effluents from septic tanks, Kiker (344) studied the percolation rates in the soil absorption systems and developed an empirical formula. Ludwig *et al.* (386) concluded from percolation tests with varying soil types that it is difficult to devise a really rational method for measuring a soil's capacity for disposing of sewage effluent. An empirical but simple water percolation test is the most practical tool for design purposes.

The purification of sewage in lagoons was discussed by Parker, Jones, and Taylor (456). They advocated two lagoons operated in series—the first, an anaerobic one for sedimentation, digestion, and partial B.O.D. removal; the second, an aerobic lagoon for complete B.O.D. removal. The purifying capacity of the anaerobic lagoon is 600 lb. B.O.D. per acre per day under summer conditions, the optimum detention time is 5 days. The maximum purifying capacity of the aerobic lagoon is 65 lb. B.O.D. per acre per day, which gives a satisfactory effluent. Algae growth increases the purifying capacity and although it makes the effluent unattractive, it tends to increase the oxygen content of the receiving water.

Dual Disposal

Hubbell (316) discussed the design and description of garbage and sewage disposal plant at Saginaw, Mich. The plant is of the primary treatment type. The garbage will be ground at the plant and mixed with raw sewage solids for dewatering on vacuum filters and incineration, or fed directly to the incinerator. This method of direct disposal was selected on the basis of cost analysis, simplicity of operation, and elimination of digester overflow problems.

Haseltine (281) discussed the various methods of adding garbage to sewage, the quantity and character of garbage, and the effect on sewage, sewers, and treatment processes. He concluded that garbage may be ground and added to sewer systems without creating serious problems, providing sewers and the treatment plant are adequately designed and constructed. If adequate capacity is not available, existing treatment plants can be altered or enlarged, but in some cases the admission of ground garbage may necessitate a higher degree of treatment.

The municipal authorities at Jasper, Ind., selected home garbage grinders as a method of eliminating garbage collection by disposal into sewers, according to Couch and Kulin (182), after consideration of other alternatives. The cost per family is estimated slightly higher than the cost by central grinding and sanitary fill. To take care of the increased load, the sewage treatment plant was enlarged by increasing the aeration, digestion, and sludge drying bed capacities.

Small Private Sewage Treatment Plants

One of the most difficult problems in sewage plant design is that of providing treatment for camps and resorts. Baffa (102) deals with this problem and stresses that although sanitary requirements are paramount for such installations, seasonal operation, cost, and operation by untrained personnel must also be considered. Typical resort and camp sewage flows are given, together with a detailed description of a typical plant using easily maintained contact beds for secondary treatment.

A larger, more elaborate sewage plant serving an airport is described by Kelez (339). In this instance, two-stage recirculating trickling filters were provided with separate sludge digestion. An interesting feature is the provision for digested sludge disposal either to drying beds or tank trucks for liquid disposal. It was noted that the airport sewage is unusually strong, ranging from 312 to 840 p.p.m. B.O.D.

INDUSTRIAL WASTES

General

Norgaard (444), discussing the significant characteristics of sewage and industrial wastes, suggests that greater attention be given to the determination of total solids, total volatile solids, suspended solids, and B.O.D. after settling, and one-day B.O.D. values. His point is that with industrial wastes the additional information will be of great value to the interpretation of the strength of the waste and that too much reliance has been placed on suspended solids, settleable solids, and 5-day B.O.D. tests. The necessity for such information has long been recognized and this article serves as a timely reminder that simple tests on raw wastes are often misleading.

An article by Rudolfs and Heukelekian (527) discussing the characteristics of industrial wastes in the Raritan River valley illustrates the point made by Norgaard that considerable laboratory testing is required to adequately determine the characteristics of industrial wastes. The problem of predicting the action of the combined domestic sewage and industrial wastes of an entire river valley, amounting to 100 m.g.d., before a collecting trunk

sewer is constructed, is discussed, and the methods of laboratory testing and results obtained are given. They conclude that in the absence of a common collecting sewer an artificial mixture of individual wastes can be made to predict the characteristics of the mixed wastes, their response to treatment, the character of the effluent, and the effect of the effluent on the receiving body of water.

Mohlman (417), discussing waste disposal as a factor in plant location, ties in such disposal problems as neutralization, reduction of oil and scum, removal of sludge-forming solids, reduction of colloidal and soluble organic matter, and removal of special and toxic chemicals to the problem of selecting a suitable plant site in order to avoid unnecessary complications and expense.

The economics of industrial waste treatment, particularly the cost of equipment used for treating metal plating, paper, and oil refinery wastes, is discussed by Calise (154)(156). An example showing the calculations for determining the economics of a white water treating system is given to illustrate some of the general economic principles involved. The author makes the rather unusual statement that if is the job of the "equipment engineer" to select the process, chemical dosages, and design equipment that will treat industrial wastes satisfactorily at minimum cost.

The problem of automatic pH control of industrial wastes is treated by Greer (271). The discussion is mainly limited to acid waste neutralization, but the principles involved apply equally to other pH control problems.

Heukelekian (291) has attempted to give the fundamental background and principles involved in the biological oxidation of industrial wastes. The general biological factors of food, nutrition, seeding, and numbers of organisms are presented in an integrated discussion. The effects of environmental factors, such as pH, temperature, oxygen supply, and toxic materials, are considered in relation to the biological oxidation requirements.

Lime

The National Lime Association is always active in providing information about the production and uses of lime. In an informative article by Boynton (127) on lime as an industrial chemical, the uses and methods of production of various limes are correlated and an insight is given into one of our largest heavy chemical industries. The National Lime Association has also published a useful bulletin (438) on the use of lime in the industrial waste field. An outline of 16 major industrial wastes is given, showing the type of waste produced, usual strengths, and applications of lime to their treatment. A bibliography for each industrial waste is included. (For other references on the uses of lime in the industrial waste field see section on "Waste Pickle Liquor.")

Radioactive Waste

In discussing the peacetime and wartime effects of nuclear fission operation, Wolman (657) has aptly said that "The Effects of Atomic Weapons" (611) should be required reading for at least a selected few in every department of health in the country. Similarly, "Health Services and Special Weapons Defense" (610) should be required reading to stimulate the rapid technical training necessary to cope with potential radiation hazards.

During the development of the first experimental reactor, the potential radiation hazards of fission were recognized. Three tolerance limits had been established and accepted as a working basis for occupational exposure prior to 1945 (162). Based on radiation effects from radium and X-ray experience, they were (a) 0.1 roentgen per day for external X and gamma radiation, (b) 1×10^{-11} curie

of radon per cc. of air in working rooms, and (c) a maximum of 0.1 microgram of radium deposited in the body of a radium dial painter.

Tentative rules and regulations for the atomic energy industry were prepared (652) concerning the maximum permissible levels of body exposure to various types of nuclear radiation; tolerance levels for air, water, and surface contamination; radiation monitoring service to determine when special protective clothing, masks, respirators, and airline hoods would be used; disposition or burial of radioactive trash, unwanted material, and equipment; and safety precautions in the shipment and transfer of radioactive materials.

The water monitoring procedures at Clinton Laboratories were reviewed by Parker (457) to assess the radiation hazards of fission products in the waste water. Animal experimentation had shown that certain elements in fission product waste were deposited in the bone and their ingestion would increase the radiation hazard to bone marrow. The daily ingestion tolerance of a single radioactive substance, based on imbibing 3 liters of contaminated water per day, was established at 0.21 microcuries of strontium, 9.3 microcuries of barium, 10.2 microcuries of ruthenium, and 3.6 microcuries of mixed fission product. Only 2.4 per cent of the activity of fission product waste overflow water after chemical precipitation, dilution, and settling was associated with suspended floc. The soluble or filtrate radioactivity consisted of 0.27 per cent barium plus strontium, 58.5 per cent zirconium, 25.6 per cent columbium, 1.69 per cent ruthenium, and less important fission elements. Thus, a tolerance concentration for ingestion could be calculated and compared with the tolerance concentration for external radiation based on total immersion of the body for 24 hr. per day. The tolerance concentration for ingesting this filtered water was calculated to be 21.6 microcuries per liter, as compared to 8.6 microcuries per liter for the external radiation due primarily to gamma rays. For the combined radiations the tolerance concentration of this water was estimated to be 1.8 microcuries per liter.

Subsequently, ingestion and external tolerance limits based on more accurate estimations of the "effective half-life" of elements having alpha, beta, and gamma radiations were published by Morgan (427) and Western (640). These "tolerance" concentrations are based on subjecting the critical tissue to not more than 1/10 to 1/100 of the maximum permissible exposure of 0.1 roentgen equivalent per day. A few of the "tolerance" concentrations in drinking water are: 0.58 microcurie per liter for Sr^{90}, Y^{90} (0.0035 p.p.b.); 3.7 microcuries per liter for Ba^{140}, La^{140} (0.0005 p.p.b.); 1,600 microcuries per liter for Cb^{95} (0.006 p.p.b.); 130,000 microcuries per liter for Pr^{143} (2 p.p.b.); and 5.4 microcuries per liter for Cs^{137} (0.0065 p.p.b.).

Parker (458) estimated that if the permissible amount of Pu^{239} deposited in the bone was taken to be 0.5 micrograms and the absorption of Pu from the gastrointestinal tract was in the order of 0.05 per cent, then the tentative permissible concentration of Pu in the drinking water would be 0.01 p.p.b.

The problems and research programs on radioactive waste disposal were discussed by Ayres (96), Beers (110), Gorman and Wolman (261), Gorman (262), Morton (430), Parkhurst (459), Placak and Morton (473)(474), Setter (553), Western (640), at a symposium (64) and elsewhere (21)(609)(612). Placak and Morton (473) present the latest permissible concentration of a dozen radioisotopes in air and water, to be published by the National Research Council in a "Handbook of Nuclear Instruments and Techniques." These permissible concentrations are compared with the

natural radioactivity of U. S. waters. The studies and research teams working on radioactive waste problems are listed and discussed.

The possibilities of biological treatment methods for the removal of radioactive elements from dilute wastes were discussed by Ruchhoft (521). A synthetic waste containing 1.4 p.p.b. Pu^{239} (approximately 100,000 alpha counts per minute per liter) was treated in a laboratory by the activated sludge process. Although the process achieved a 96 per cent removal of alpha activity in 24 hr. of treatment, the effluent quality fell short of the goal of 0.001 p.p.b. or 70 counts per minute per liter. A two-stage treatment study using supplementary nutrients to feed the zooglea organisms was underway. This study was reported in greater detail by Newell (442).

The Atomic Energy Commission retains the power of control over the use of radioisotopes and the disposition of radioactive wastes. As a guide to off-commission users, the Isotopes Division of the AEC provides interim recommendations for the safe disposal of radioactive wastes (6). The recommendations for radioiodine permit disposal by dilution with water or stable iodides and water provided (a) regular radiation surveys of plumbing fixtures are made, particularly before their repair; (b) a maximum of 200 millicuries are disposed per week; and (c) the flow in the main sewer of the institution is sufficient to dilute the radioiodine to 0.5 microcuries per liter, or, if 1 g. of KI is added to each millicurie of radioiodine, the radioactivity should not exceed 10 microcuries per liter. Isotopic dilution, or the adding of relatively huge quantities of stable isotope to a radioisotope in the same chemical form, was considered a feasible method of preventing hazards due to ingestion. Recommendations for the safe disposal of P^{32}, C^{14}, and other isotopes were also given. Butrico (150) concluded that the "Interim Recommendations" were ultra-safe when applied to a Massachusetts hospital. However, Scott (546) estimated that the external radiation hazard due to the disposal of radioiodine according to the "Interim Recommendations" might be significant. The estimations considered radiations from park grounds that were fertilized with sewage sludge from a treatment plant receiving radioiodine hospital wastes. It was presumed that the radioiodine in the sewage would be absorbed by settleable solids and concentrated in the chemically conditioned and vacuum filtered sludge.

Wastes from Atomic Weapons

Radioactive hazards and air, water, and surface decontamination problems associated with the use of atomic weapons appear foreboding (91)(178)(610)(611). Certainly, the current maximum permissible exposure of 0.3 roentgens per week of X or gamma radiation (424) would not be a realistic tolerance for short-time exposures. According to Cooney (178), a full-body irradiation in the order of 25 to 100 roentgens has been given to patients for treatment of various conditions and an exposure to 200 roentgens may be considered an acute dose, which may cause radiation sickness in 50 per cent of humans. Further guidance is needed on correlating the risk attached to varying levels of internal and external exposure.

The gamma radiation from the fission products of a single "nominal" atom bomb (611) decreases rapidly after detonation, due to radioactive decay. Nevertheless, the residual radioactivity after one week and one year from the time of detonation has been estimated to be 13,000,000 and 110,000 curies, respectively. Depending on the altitude of detonation, a varying percentage of fission products will contaminate the area in the vicinity of the bomb burst. The blast effects of the bomb are most devastating

at relatively high altitudes of detonation. In this case, the fission products are dispersed in the upper atmosphere and local radiation hazards immediately following the bomb burst are relatively minor. However, the detonation of the bomb at low level, underground, or under water may result in prolonged problems of radiation hazard and surface contamination.

Water supplies and sewage containing fission products and decontaminating fluids will require treatment necessary for the removal of the more hazardous fission products as differentiated from the less harmful radioactive isotopes of short "effective half-life."

In the fission of unstable heavy elements a variable yield of fission product results from fast and slow fission of U^{235}, Pu^{239}, etc. (91)(180)(363). The radioactive isotopes have specific rates of decay, varying from half-lives of seconds to years, and each isotope may decay through three or four generations of "daughter" isotopes. The concentration of any particular isotope depends on the time since fission occurred. Short-lived isotopes, which represent a large fraction of the yield at the time of fission, decay to other isotopes and, conversely, long-lived radioisotopes, which represent a minor fraction of the yield at the time of fission, become important fractions at a later date or become important due to the accumulation of "daughter" isotopes.

The more important radioactive isotopes remaining some weeks or months after fission are Sr^{89}, Sr^{90}, Y^{90}, Zr^{95}, Cb^{95}, Element 43^{99}, Ru^{103}, Ru^{106}, Rh^{106}, Sn^{121}, Sb^{125}, I^{131}, Cs^{137}, Ba^{140}, La^{140}, Ce^{141}, Pr^{143}, Ce^{144}, Pr^{144}, Nd^{147}, induced activity in elements near the bomb burst, and residual alpha-emitting heavy elements (91).

Safety measures and instruments for monitoring personnel, contaminated areas, and laboratories have been reviewed by Andrews (19), Dauer (186), Ingram (326), Morgan (424), Morgan (426), Rodger (514), and in chapters on health physics and instrumentation in nuclear physics text books (91)(180)(363). Special laboratory safety procedures and equipment have been described by Tompkins (599)(600).

Texts on the chemistry and separation of the heavy metals, rare earths, and other fission products have been or are being released in the NNES (National Nuclear Energy Series) for publication. Tompkins, Farabee, and Khym (601) developed a procedure for the simultaneous radiochemical analysis of barium, strontium and rare earths in urine by phosphate precipitation, the use of a cation exchanger to remove phosphate ions, and separation of radioactive ions by elution, followed by chromate precipitation to separate strontium and yttrium from calcium and magnesium. Studies were reported on the effect of pH on the solubility of rare earth and thorium phosphates and polyphosphates (153), the purification of protoactinium by anion exchange resins (357), a rare earth separation by anion exchange (317), the separation of hafnium from zirconium by absorption on silica gel (277), the separation and mounting of fission elements by electrodeposition (371), a precision method of counting radioactive liquid samples mounted below a thin window G–M tube (237), and a portable scintillation spectrometer consisting of a 100-g. alkali halide crystal and photomultiplier having a detection sensitivity of 10^{-10}r. per sec. (488).

An increasing amount of nuclear science literature is being declassified. These AEC documents and the *Nuclear Science Abstracts* can be obtained from the Technical Information Branch, Atomic Energy Commission, Oak Ridge, Tenn.

Packinghouse Wastes

Packinghouse losses of about 4.0 lb. of grease per 1,000 lb. live weight of

animals killed should be possible in a well-equipped packinghouse, according to Bradney, Nelson, and Bragstad (128). The Sioux Falls, S. D., sewage treatment works receives about the maximum load of packinghouse waste of any municipal plant, and salvage of grease and nitrogen losses has been accomplished by installation of grease skimmers and evaporators in the packinghouse. Modification of the clarifiers by the authors has eliminated the rising sludge problem. The final effluents in 1947 contained only 13 p.p.m. suspended solids and 12.3 p.p.m. B.O.D. A primary, backwashed high-rate filter was very helpful in improving operation of the secondary trickling filters, with loadings up to 15,000 lb. B.O.D. per acre-foot per day. Discussion by Sawyer urged further recoveries in the packinghouse, citing standards suggested by Mohlman.

Characteristics of wastes from chicken packing plants were discussed by Heukelekian, Orford, and Cherry (292). Flows averaged 2,600 to 7,000 g.p.d. per 1,000 chickens killed (3 lb. each, live weight); B.O.D. and suspended solids averaged 500 and 800 lb., respectively, for combined wastes, reduced to 147 and 220 lb. if manure is first removed. Basket screens are effective in removal of manure, and sedimentation removed 85 per cent of suspended solids from mixed wastes, but only 25 to 35 per cent of B.O.D. Alum improved removals, but lime was ineffective. The sludge appears to digest readily. Porges (479) describes wastes from poultry dressing, in Kansas, and gives various unit losses, totaling population equivalents of 125 for B.O.D. and 75 for suspended solids, per 1,000 lb. live weight. These values are somewhat lower than reported in the Ohio River Pollution Survey of the U.S.P.H.S.

Suggestions for prevention of losses in the meat packing industry are made by Putnam (493). Dry rendering, installation of screens in drains, mechanical removal of manure and paunches, and proper operation of skimming basins are the major suggestions listed.

Experiments on anaerobic digestion of packinghouse wastes at the Hormel packinghouse in Austin, Minn., are described briefly by Fullen and Murphy (240). Further data are expected to demonstrate the feasibility of the process. Rowntree (519), in Auckland, New Zealand, has reported on recommendations for treatment of packinghouse wastes in that city, with a volume of 4 m.g.d. Plant-scale tests of anaerobic digestion are recommended. No final report will be made until these experiments are completed.

Fermentation Industries

The butanol-acetone works of the Commercial Solvents plant (643) at Peoria, Ill., studied anaerobic digestion of wastes and estimated a plant to remove 70 per cent of the B.O.D. would cost $438,000. This expensive process was abandoned because it was found that riboflavin could be recovered from the waste and sold at a profit. Evaporators were installed, therefore, to recover 28 to 32 tons of dry feed. Further equipment was installed in 1949 to increase total drying capacity to 70 or 80 tons per day. Thus, the waste problem may be considered solved.

The waste disposal plant of the Upjohn Company at Kalamazoo, Mich., has been described by Hilgart (297). This plant makes antibiotics (penicillin and streptomycin) and has capacity for a flow of about 700,000 g.p.d. The B.O.D. load is about 3,000 lb. per day, which must be reduced to about 100 lb., because of limited dilution in the small stream. The plant consists of holding tanks, preliminary aeration for 5 to 10 hr., preliminary settling tanks, two 90-ft. filters to be operated at 1,500 lb. per acre-ft., and final settling tanks. Sludge has not digested well and some of it must be hauled away and buried. However, filter

effluents have been excellent and the plant is considered quite successful. It will be noted that the liquor undergoes no anaerobic fermentation.

The problem of distillery waste salvage and final treatment has been discussed by Davidson (187). Evaporation will remove 98 per cent of the B.O.D. in the thin slop, which contains from 2.5 to 5.5 per cent solids, mostly in solution. Disposal plant treatment of residual wastes increases the overall removal of B.O.D. to 99.9 per cent. Discussion by Tatlock referred to a treatment plant of the National Yeast Corporation at Crystal Lake, Ill., where digesters of 2.6- to 3.5-day capacity are followed by a high-rate trickling filter.

Davidson (188) described a treatment plant for the disposal of residual distillery wastes, following evaporation of the spent mash. By use of primary settling, a 62-ft. diameter filter, and a final clarifier, the final effluent is expected to contain about 50 p.p.m. B.O.D., a removal of 99.9 per cent.

Compressed yeast wastes from the Anheuser-Busch Company have been studied by Rudolfs and Trubnick (528). The plant consisted of digesters, settling tanks, trickling filters, and final sedimentation. Digesters were loaded at 0.1 lb. B.O.D. per cu. ft. per day and filters at a rate of 5 lb. per cu. yd. per day (8,065 lb. per acre-ft.). Over-all reductions have averaged 90 per cent, with the effluent containing an average of 120 p.p.m. B.O.D.

Buswell (147) discussed anaerobic treatment of yeast and distillery wastes. Loadings of 0.14 lb. of B.O.D. per cu. ft. per day have been feasible in many pilot-plant studies, and existing plants loaded at 0.1 lb. per cu. ft. per day regularly produce 70 to 80 per cent improvement in the quality of the waste.

Waste disposal at a modern brewery was described by Schneider (542). The plant consisted of a fine screen, settling tanks, two bio-filters 60 ft. in diameter and 3 ft. deep, recirculating pumps, secondary settling tank, a sludge digestion tank, sludge drying beds, and 32,000 sq. ft. of percolation beds containing 4 in. of sand over a 2-in. gravel layer. The B.O.D. was reduced from 445 to 65 p.p.m., or 88 per cent, and the suspended solids from 200 to 25 p.p.m., also 88 per cent.

Salvage of brewery wastes was discussed by Schmidt (541). Grains are used as cattle food, hops are used by farmers, and spent yeast is dried and sold as an animal food supplement. Residual wastes will require some degree of treatment before discharge.

Growth of yeast on brewery waste was studied by Lin (378). The B.O.D. was reduced 55 per cent by conversion of dissolved solids into yeast cells. The incubation period was four days. The process was considered only available as a "roughing" unit in conjunction with subsequent biological treatment by trickling filters or activated sludge.

Chemical and Pharmaceutical

Treatment of wastes containing formaldehyde has been described by Dickerson (198). The wastes contained about 675 lb. of B.O.D., mostly formaldehyde in various concentrations. The filter was 37 ft. in diameter and 6 ft. deep, loaded at 4,500 lb. per acre-ft. Removals were low and the filter ponded. An equalizing tank was installed and ammonia plus phosphate added. Results improved very much during the summer. Best removal of B.O.D. by the filter was 28 per cent. Gellman and Heukelekian (253) have worked on laboratory studies of the biological oxidation of formaldehyde. Concentrations up to 130 p.p.m. were oxidized, but between 135 and 175 p.p.m. proved to be toxic. By development of an effective flora, up to 1,750 p.p.m. could be oxidized. Nitrogen (as ammonia) was added to satisfy a B.O.D.: N ratio of 40 to 1, and the pH was held above 6.0. The sludge

consisted largely of bacterial aggregates.

Treatment of phenolic plastic wastes has been described by Kirchgessner (345). Phenol is recovered by centrifuges, which remove it from emulsions. Extraction of phenol also is accomplished by washing with benzene. At a cost of $150,000, about 7,000 lb. of phenol per day is recovered from the sewers.

Waste abatement problems of the Carbide and Carbon chemicals plant at South Charleston, W. Va., have been described by Lyon (388). Salvage of insoluble wastes and use of closed cycles on processing equipment have resulted in some abatement of pollution, to be increased by final treatment of waste, if necessary.

Pulp and Paper

In the literature on pulp, paper, and paperboard wastes published in 1950, the control and treatment of kraft mill waste was represented by a number of important articles. Moggio and Gehm (415)(416) reported experiments conducted for the purpose of determining factors whereby oxidation of the waste could be accelerated. It was found that pre-aeration had a stimulating effect on microbial oxidation and the addition of relatively small amounts of seed material developed from the waste itself, in conjunction with the addition of small quantities of nitrogen and phosphorus salts, increased the rate of B.O.D. reduction substantially. A treatment process consisting of the addition of nutrient salts and a small quantity of returned seed sludge, followed by a short period of aeration and storage, was devised on the basis of the laboratory experiments and will be developed on a pilot-plant scale.

Porter and Bishop (482) describe the treatment process employed at a southern newsprint mill. Total mill effluent, consisting of kraft pulping waste, groundwood waste, bleachery effluent, and machine waters, is treated by settling and storing in two ponds in series totaling 500 acre-ft. in capacity. An average reduction in B.O.D. of the waste from 230 p.p.m. to between 30 and 40 p.p.m. was observed over the summer months at a storage period of approximately 20 days. The necessity for presettling was stressed and the installation of basins for this purpose is described.

Barnes, Moggio, and Colmer (103) developed a medium for determining total numbers of bacteria in kraft mill waste undergoing stabilization. Stimulation of growth occurred during the first six days of storage when nitrates were added to the waste. Predominating organisms appearing in waste undergoing microbial oxidation were of the genii *Pseudomonas* and *Florabacterium*. When these organisms were added singly to the waste, little oxidation occurred. However, a mixture of the two forms produced a substantial B.O.D. reduction when grown in the waste.

That the pH value of kraft mill waste is a fair index of its pollutional strength was concluded by Van Horn (615) from a long series of tests on individual waste samples, in which this value was correlated with the B.O.D. resin acid, mercaptan, and sulfide content of the waste. The same author (616) reported on the causes and reduction of tastes and odors in waters containing kraft wastes. Sulfur compounds were found to be mainly responsible. Taste and odor producing capacity could be reduced but not eliminated from the waste by chlorination. It appeared that the chlorination of fractions of the waste, rather than the whole, would be about as effective, and considerably less costly than treatment of the whole. Van Horn, Anderson, and Katz (617) (618) demonstrated that on dilution with receiving waters, concentrations of substances potentially harmful to fish were too low to cause damage from kraft mill waste. The survey

upon which these conclusions were based embraced five Wisconsin kraft mills.

Holderby and Wiley (306) compared the efficiency of biological processes for the treatment of spent sulfite liquor with fermentation by-product processes. This comparison indicated that treatment processes were, at their present stage of development, too costly for application because of their low efficiency. Yeast production led all other processes in terms of efficiency based on B.O.D. loading per cubic yard of plant capacity. It also recovers a portion of the nutrient salts which must be added in all treatment or fermentation processes. This process was over 10 times more efficient than the most effective treatment system.

A process for treating spent sulfite liquor by heating under pressure to temperatures above 400° F. for short periods of time was investigated by Bruns (135). Hydrolysis of the sugars and precipitation of lignins and other liquor components caused substantial reduction in B.O.D. value of the waste. Preliminary research on the variables affecting the process is presented in this report. Experiences in the disposal of sulfite liquor by employing it as a road binder without preconcentration are related in an article by Sherman (554). A large portion of the liquor solids from a small mill located in a rural area are employed in this manner. Hagglund (276) commented on the existing research in evaporation and burning of calcium base sulfite liquor; Rogers and Jolley (516) present experiments on burning the liquor without auxiliary fuel under a large boiler. These tests indicated the necessity for obtaining the liquor in high concentration, preheating it, and injecting it into the furnace in such a manner that the flame produced causes further evaporation of the atomized liquor as it leaves the burner nozzle. Similar tests by Kennedy and Coldwell (341), but employing pulverized coal as a supplemental fuel, were made. It was estimated that more than 6 lb. of steam at 212° F. was obtained per pound of dry liquor solids. Progress in magnesia base sulfite process operations is traced by Hazelquist and Rogers (285). Plant and operating changes have improved recoveries of sulfur, magnesia, and heat to a considerable degree over levels previously possible. Benson (112) enumerates the advantages and disadvantages of the ammonium bisulfite process as a means for preventing liquor discharge into surface waters. A summary of processes utilizing sulfite liquor, consisting of a collection of papers and brief bibliography on this subject, was published by the Forestry Committee, Research Council of Ontario (57).

A research report on the nature and treatment of semi-chemical pulping waste was presented by Murphy and Kress (436). The relation between chemical and sanitary analyses indicated that fatty acid salts were responsible for most of the B.O.D. of semi-chemical pulping wastes and that their color was caused mainly by lignins. Chemical coagulation tests employing lime and recarbonation were effective in removing most of the color, but only a small percentage of the B. O.D. Aerobic oxidation after the addition of nutrient salts was capable of producing high B.O.D. reductions, but the extensive treatment facilities required for practicing such processes make them impractical. Preliminary experiments on high-rate anaerobic digestion were also reported in this bulletin.

Development of a method for treating strawboard wastes by sedimentation followed by anaerobic digestion is described by Bloodgood (118). Sedimentation removed 30 per cent of the B.O.D. and digestion consistently produced effluents below 150 p.p.m. B.O.D. when treating rotary beater-washing wastes. Maximum loadings were not yet established for the diges-

tion process due to mechanical difficulties in the pilot plant. Primary sludge proved costly to dewater by vacuum filtration due to high conditioning chemical requirements. Lardieri's (364) work on the organic constituents of a strawboard rotary liquor showed a pentosan content of over 28 per cent on a dry solids basis. Because of this, utilization of the liquor for growing molds used in the commercial production of riboflavin was initiated.

An experimental plant for treating de-inking waste by clarification and oxidation is described in two articles by Palladino (454)(455). Design details and capacities involved are presented.

Continuing interest of the industry in the clarification of machine waters, as well as recovery or disposal of the sludges produced, is demonstrated by the number of articles appearing on this subject. Kominek (354) concluded from the operation of three "Cyclator" installations clarifying board and tissue white waters that a removal of suspended matter in excess of 95 per cent could be obtained if effective alum and activated silica application is made. Slurry recirculation eliminated difficulties caused by waste temperature fluctuations of less than 3° F. per hour. The elimination of entrained air appeared imperative to proper functioning of the unit.

Application of a new type of rotary gravity filter, which employs a sheet of wet pulp as a filter medium, to white water filtration is expounded by Perkins (468). Results of tests on the overflow white waters produced by many different furnishes revealed that a high degree of clarification could be obtained at practical filtration rates. Successful application of this device in a tissue mill is recounted by McGinn (402). Effluent suspended solids levels well below 0.2 lb. per 1,000 gal. could consistently be obtained with this device. Water and fiber recovery by clarification in a flotation save-all is discussed by Easton and Baum (208). Particular attention is given to the use of colloidally active materials, such as glue, silica, and resins, in increasing the efficiency of the flotation unit.

Both Calise (155) and Gehm (248) discussed the factors involved in the proper installation and operation of machine-water clarifying systems, stressing the need for minimizing variables affecting performance. Two related papers by Nemerow (440) and Rudolfs and Nemerow (529) deal with the factors affecting satisfactory reuse of news and chip mill white waters and clarifier underflows. It appears from these studies that microbial development, rather than fines, is responsible for difficulties experienced in their re-use. Methods which control the development of microbial slimes are effective in allowing high degrees of water recirculation without causing process difficulties. Voegler and Rudolfs (628)(629) presented detailed studies on the factors involved in draining and dewatering board mill white water sludges. Much basic information contained in these reports can be employed for calculating drying bed and lagoon areas required for disposal of such materials. Dewatering efficiencies of various types of filters operating on underflows from paper mill waste clarifiers was the subject of a paper by Behn (111). The wide variation between different types of sludges and the necessity for pre-thickening some of them prior to filtration was brought out. Anaerobic digestion of board mill white water, highly concentrated in dissolved solids by repeated circulation, was accomplished by Amberg (14). A 71 per cent reduction in B.O.D. was obtained at digester loadings of 0.044 lb. per cu. ft.

Development and pilot-plant work at eight paper mills is described by Gehm (250).

The pollution arising from the different methods of pulping and paper

production and the methods of abatement of such pollution is discussed in a general way by Doutt (205). The problems of the pulp and paper industry are also discussed by Savage (537) and Koch (351).

A system of recovery of industrial process waters in general and of paper and paperboard mill waters in particular is described by Ehemann, Burnett, and Waddell (217). The OCO system consists of selective return of high solids process waters to the system and filtration of the remaining low solids white water so that the solids can be recovered as furnish. The clear water can be utilized in showers.

The dechlorination of black liquors derived from soda cooking of hemp and rags, with subsequent bleaching of the fibers to prepare the waste for ultimate biological treatment, is discussed in "Water Pollution Research" (635). The waste water was neutralized with carbon dioxide, diluted to a B.O.D. of 150 to 200 p.p.m., and applied to a biological filter at the rate of 60 g.p.d. per cu. yd. A satisfactory biological film developed and an effluent of 20 p.p.m. B.O.D. was obtained.

In the production of alcohol from wood sugar derived from sawmill wood waste, the stillage contains large quantities of pollutional materials, such as lignin, furfural, methanol, organic acids, and unfermented sugars, which raise a disposal problem. The waste has a high B.O.D., is high in color, has an odor, and is destructive to fish life. Bollen (122) studied methods of treatment of the waste. The treatment of the stillage for yeast production removes only 40 per cent of the B.O.D.; the recovery of xylose would lower the B.O.D. by about 25 per cent. The aeration of the waste after inoculation with *Oidium lactis* and *Pseudomonas aerogenosa* with supplementation of nitrogen gave 25 to 30 per cent B.O.D. reduction in 5 days. Ponding with percolation gave 90 per cent B.O.D. reduction, but the percolation through soil was too slow to be practical. Trickling filter treatment showed promise.

Cannery Wastes

Treatment

Canham (161) reports that open-pond anaerobic digestion of mixed tomato and lima bean wastes held at an average detention time of 2.53 days effected an average B.O.D. reduction of 39.8 per cent, equivalent to 14.2 lb. per 1,000 cu. ft. of digester per day. Comparable reductions in suspended solids and soluble solids were obtained. The anaerobic digestion ponds operated without objectionable odors detectable beyond a distance of 500 ft. at times of maximum odor production. Digester effluents were lagooned for further purification, which proceeded without objectionable odors. Combined anaerobic digestion and lagoon storage reduced raw screened wastes, which had an average B.O.D. of 982 p.p.m., to 57 p.p.m. within the 52-day canning period.

Studies were conducted by Drake and Bieri (207) on lagooned wastes from the canning and freezing of peas, corn, beans, and carrots. The course of stabilization taking place in the lagoon was followed analytically and by observations on the development or absence of odors. Sodium nitrate dosages considerably in excess of the general criteria of supplying 20 per cent of the oxygen demand were found to be necessary for odor control. Ryan (530) presents a general discussion of the use, construction, and operation of lagoons for canneries and slaughterhouses.

Sanborn (533) reports on the odor and waste disposal problems occurring at pea viner stations. Control measures to fit varying conditions are given. O'Connell and Fitch (445) present a theoretical discussion of the costs of disposal of cannery garbage solids from a hypothetical cannery by discharge into sewers for subsequent

handling at a municipal treatment plant in comparison with disposal by dumping on land or by drying.

Jenks (330) discusses the handling of cannery wastes in California municipal sewage ponds. Pilot-plant studies at two municipal sewage works involved recirculation of ponded wastes through a bio-filter, which functioned as an aerator. The use of ponds in place of more expensive clarifier structures was considered practical for purposes of detention and settling, provided recirculation with concomitant re-aeration was maintained at all times. Following these studies, the contents of 20 acres of oxidation ponds at Modesto were aerated through a series of hydraulic jumps on an inclined plane. An analytical evaluation of the operation of the aeration ponds was not given.

A brief description is given by Grant (266) of the municipal treatment plant at Winchester, Va., designed to handle combined domestic sewage and apple canning wastes by two-stage high-rate filters with recirculation. During the apple season combined wastes have 600 p.p.m. B.O.D. and 575 p.p.m. suspended solids.

Recovery

Brown, Ramage, and Owens (131) discuss the problems encountered in the recovery of usable products from pear waste. The results obtained in a large pilot plant for the conversion of pear waste to pomace feed and molasses are described. Neubert *et al.* (441), also working with pear wastes, describe the preparation of an edible sweet syrup. A process for the concentration of juice from waste apple cores and trimmings to an apple juice concentrate without loss of apple essence is described by Miller (406). The commercial conversion of waste from a group of sardine canning plants to fish oil and meal and condensed fish solubles is described (56).

Dairy Wastes

Waste Saving

All the papers published during the year on dairy waste stress waste saving. Sanders (535) discusses the importance of industrial sanitary engineering in dairy plant management.

Agar (7) stresses the importance of waste saving, by-products utilization, and flow equalization.

In reviewing the activities of the Task Committee on Dairy Waste Disposal of the Dairy Industry Committee, Putnam (494) discussed progress in waste prevention, Gaumnitz (247) reviewed methods of instigating research on dairy waste under the Research and Marketing Act, and Campbell (160) gave a description of the Dairy Industry Committee exhibit on waste saving at the exposition of dairy equipment in 1949.

A report on waste prevention by the Task Committee on Waste Disposal of the Dairy Industry Committee (592) gives specific advice for waste saving, waste measurement, and sampling. The information was summarized from earlier papers by various members of the Committee. The report contains much good advice about waste saving, but very little about waste disposal.

A dairy waste-saving and treatment guide for milk plant operators (185) was issued by the Dairy Sanitation Engineers Committee, Pennsylvania Association of Milk Dealers, in cooperation with the Pennsylvania Sanitary Water Board. This guide gives information in regard to "standard" losses in the industry, waste prevention methods, waste measurement, sampling methods, analytical methods, and treatment methods. It offers four suggested plant designs suitable for small milk plants producing less than 10,000 g.p.d. of waste with less than 140 lb. of B.O.D. Three of the suggested designs are for treatment units of the return sludge type; the fourth is for a unit using a recirculating

trickling filter. The standard losses mentioned are the same as those suggested by Trebler and Harding in 1947. They have also been listed elsewhere (68) (185).

The 85 per cent reduction in B.O.D. load required by Pennsylvania for wastes discharged to clean streams is based on the standard losses for the plant operations. Thus, a reduction in actual losses below the standard is credited as part of the treatment. This has given a tremendous boost to the waste-saving efforts of the dairy industry in Pennsylvania and has probably done more to reduce pollution due to dairy waste than the construction of any number of costly disposal plants.

Anaerobic Digestion

Spaulding (567) obtained 90 to 99 per cent B.O.D. removal from synthetic milk waste, having 380 to 3,300 p.p.m. B.O.D., in agitated laboratory digesters kept at 88° F. with six-day retention and a tank capacity corresponding to 0.034 lb. B.O.D. removed per cu. ft. If one could learn how to control this type of treatment on a commercial scale, it might make the cheapest method for disposal of dairy waste.

Backmeyer (99) has successfully continued the feeding of whey directly to the sludge digesters at Marion, Ind. During a strike in a milk plant, a load of 11,000 gal. of whole condensed milk was added over a two-day week-end period to a 70,000-cu. ft. digester. There was a large increase in gas production, but no bad effect on the performance of the digesters. Undoubtedly, if for some reason dairy products or strong dairy wastes have to be disposed of in a hurry, it is far better to truck them to a city disposal plant and feed them to the digester for anaerobic digestion than to let them go down the sewer and upset the entire plant.

Trickling Filters

Trebler and Harding (602) reported on the operation of four National Dairy trickling filter plants, some of which had been in successful operation for several years. Two-stage, high-rate filters have proven successful for treatment of dairy wastes, but the sludge is not yet being handled in an economical and satisfactory manner. Also, the two-stage operation may not be sufficiently better than single-stage to justify any marked difference in installation and operating cost. However, with the National Dairy design, using split clarifiers and concentric arrangement of the two stages of the filters, the cost difference is small.

Evidence is presented indicating that there is no known upper limit to applied B.O.D. loadings or to pounds B.O.D. removal per unit volume (or area) of a trickling filter, but that the quality of the effluent becomes so bad at high loadings that it may not be practical to use them, except possibly for pretreatment of strong organic waste before discharge to city sewage plants.

Gloyna (258) described treatment of a synthetic skim milk waste on 18-in. diameter experimental trickling filters, 1 to 7 ft. deep, with hydraulic loadings of 3 and 20 m.g.a.d. under controlled conditions of temperature and organic loadings. Recirculation ratios from 1:1 up to 6:1 were tried. The author concludes that the rate of B.O.D. removal for all filter depths increases with an increase in hydraulic loading and that the average rate of B.O.D. removal for all filter depths is about the same when the hydraulic loading is kept approximately the same and different recirculation ratios are used. Apparently these conclusions apply only to the so-called "removable B.O.D.", which varied from 82 per cent at the 1:1 recirculation ratio to 94 per cent at the 6:1 recirculation ratio.

Activated Sludge

Hoover, Porges, and collaborators (308) (478) (480) (481), have made laboratory investigations of the aeration and biochemical oxidation of synthetic milk wastes consisting of a 0.1 per cent solution of skim milk powder at 86° F. by means of pure and mixed cultures of microorganisms. The first two papers were preliminary reports. Two subsequent papers contain more complete data. A chemical oxidation (C.O.D.) method (Eldridge) and lactose and protein analysis were used to follow the biochemical reactions. Violent mechanical agitation and, apparently, a great excess of air were used to maintain strictly aerobic conditions. No quantitative data on air consumption are given.

In some experiments (308) with a mixed flora (obtained from an activated sludge plant operating primarily on dairy waste), 50 per cent of the influent C.O.D. was eliminated by oxidation, while 45 to 48 per cent was assimilated into the cell tissues and could be easily removed by centrifuging, even though the settling characteristics of the sludge were unsatisfactory. Lactose was completely removed from solution, while a small amount of other substances remained.

Later work with various pure cultures of bacteria and yeasts (478) (480) showed that, for instance, *B. polymyxa* removed both protein and lactose almost completely in 72 hr., but the cell substance was increased so that there was actually only 20 per cent total C.O.D. reduction. *S. fragilis* gave complete lactose removal, but the protein fraction remained fairly constant. The total C.O.D. removed was insignificant. A coliform organism isolated from cow manure used up most of the protein, but very little lactose, with apparently no reduction in total C.O.D.

Neill (439) described the return sludge treatment plant for cheese plant wastes at the Belle Center Creamery and Cheese Company. A total of about 25,000 gal. of cheese plant waste, including condensate from the vacuum pans, was being treated daily in two aeration units. The B.O.D. of the raw waste averaged 1,200 p.p.m. and was reduced by treatment to less than 19 p.p.m. in the effluent. Normally, about 420 c.f.m. of air at 6 p.s.i. is provided, although 630 c.f.m. can be supplied for pre-aeration, return-sludge air lift, and aerators. Excess sludge is thickened and treated in an 11,000-gal. digester heated to 100° F. with direct steam. No sludge was discharged from the digester in 10 months' operation. [Note: it has later been reported that no sludge had been discharged from the digester in more than 30 months' operation. However, the capacity of the digester proved insufficient to handle all of the excess sludge.]

Johnson (333) gave a preliminary report on treatment of cheese waste by aeration in two plants in Missouri. Indications were that 50 per cent B.O.D. removal could be obtained by simple aeration with a baffle in the aeration tank providing some settling and sludge return within the tank. McKee (403) reported on one of the same plants and on two others with somewhat similar arrangements. In all three plants B.O.D. reduction and effluent quality leave a great deal to be desired. Consequently, they can only be considered as partial treatment plants.

Hasfurther and Klassen (282) described the Dean Milk Company dairy waste disposal unit at Huntley, Ill. The plant is of the activated sludge type and at the time of the tests was using impingement-type aerators. The results of the tests were not very satisfactory, and the authors drew the conclusion that good air diffusion is extremely important. [Note: Since these tests were run in the fall of 1949, the aeration system has been changed and improved results obtained.]

Tannery Wastes

Vrooman and Ehle (630) report the results of successful pilot-plant studies where the digestion of sewage and tannery waste sludges were accomplished. This experimental work was done at Gloversville, N. Y., where tannery waste makes up a large portion of the city's sewage. Smith (565) indicates that the best temperature for digesting sewage and tannery sludge is 95° F. or higher. The Washington State Pollution Control Commission (218) has established specific requirements for the treatment of tannery wastes, including regulations on screening and the disposal of lime sludge, vegetable tan liquors, beamhouse wastes and chrome liquors.

Textile Wastes

The New England Interstate Water Pollution Control Commission (63) has compiled a review on textile wastes for the period 1936–50. Much of the reported work on textile wastes has been about experiences in states along the Atlantic coast. McCarthy (398) tells about the work done on wool dyeing wastes at the Lawrence Experiment Station. He points out that wool dyeing wastes are stronger than domestic sewage, but not as strong as wool scouring wastes. The volume of waste is much larger per pound of wool than experienced in wool scouring. Very little treatment can be obtained with coagulation and sedimentation. The wool dyeing wastes can be treated on trickling filters with loadings comparable with those applied to filters handling domestic sewage. The wool dyeing wastes cause no particular difficulty when mixed and treated with domestic sewage.

Coburn (174) describes the wastes from the Lees carpet mill in Glasgow, Va. There are two wastes from this mill: one, a strongly alkaline scouring liquor containing considerable quantities of dirt, burrs, grease, suint, excreta, and other substances removed in washing raw wool; the second, a highly colored spent dye liquor. The wastes are collected separately, then mixed, then acidified for grease separation. The acidified wastes are flocculated and settled, after which the effluent is neutralized before discharge to the Maury River. The sludge produced by chemical treatment is pumped to sludge lagoons. In the process of treatment the B.O.D. is reduced from 2,260 p.p.m. to 915 p.p.m. and the grease is reduced from 1,600 p.p.m. to 51 p.p.m. The plant treats about 180,000 g.p.d.

Bogren (120b) says that peroxide kiers, bleaching, dyeing, mercerizing, and sundry special finishing process waters together with large quantities of wash waters and a small amount of domestic sewage can be treated by high-rate trickling filters, as demonstrated by 60 per cent B.O.D. removals in the pilot-plant studies.

Coburn (173) presents information on pilot-plant studies that compared high-rate trickling filters and chemical treatment of cotton printing and finishing wastes. The conclusion drawn was that the high-rate trickling filters present fewer complications in operation and a less serious sludge disposal problem than does chemical treatment. The data indicate that the B.O.D. reduction (70%) for the high-rate trickling filters was considerably higher than for chemical coagulation with alum. On an original construction cost basis the chemical treatment plant would be the cheaper.

Bogren (120a), in another article on the treatment of wastes from a cotton finishing plant, gives the volumes and character of wastes from mills of this type. A bibliography is presented in connection with the discussion of neutralization, precipitation, and biological treatment of these particular wastes.

McCarthy (399), in a discussion of textile wastes, points out that some streams can be used to receive textile wastes providing elimination of exces-

sive losses of organic materials from the mills is practical.

A very interesting chemical and biological method of treating silk dyeing wastes is presented by Jung (335). The method, which is applicable to the straight industrial waste or to sewage containing these wastes, consists of: first, acidification by bubbling with flue gas; second, filtration through a bed of iron turnings, or passage through a revolving drum containing iron turnings; third, diffused aeration to oxidize the ferrous iron; and fourth, aeration and final settling using return sludge similar to activated sludge.

Wool Scouring Wastes

Cameron (157) has given the history of the waste treatment works for a wool scouring plant. He also discusses the use of hypochlorite as an aid in grease recovery. Ryder (531), in his paper on a Glasgow, Va., carpet mill, describes the layout of the treatment plant and gives data on the equalization, flocculation, settling, and acid mixing tanks as if they were for a wool scouring mill, whereas, Coburn, in his discussion of the same plant, thinks of the wastes from this particular mill as being textile wastes.

Plating and Cyanide Wastes

Pointing out that there is no economically practical method for treating dilute cyanide wastes, Milne (411) discussed the HCN/CN equilibrium in natural waters. This ratio is determined by pH and dilution, and the misconception that no HCN exists in neutral or alkaline solutions should be guarded against. He noted that fish toxicity tests involve placing the fish in a cyanide solution and aerating; if the cyanide waste is diluted with water high in bicarbonates the solution will be buffered in the neutral pH range and the fish will be exposed to hydrocyanic acid instead of cyanide ion. However, continued aeration will cause a loss of HCN, and, for reliable toxicity tests, this loss should be made up. In another paper (412) he presented the physical chemistry of cyanide complexation as a basis for a proposed treatment method. Although many metals form cyanide complexes, all except nickel can be eliminated as practical treating agents. The fact that nickel solutions are commonly wasted from plating plants provides the electroplater with a cyanide disposal method at no additional cost, because formation of nickelocyanide will maintain the cyanide concentration below toxic levels in effluent water. It is only necessary to keep the Ni/CN ratio above 0.56 at the moment of mixing the two solutions and to follow a proper mixing sequence. Sludge blanket operation is recommended to insure good contact.

In a study of the reaction of sodium and calcium hypochlorites with buffered alkaline solutions of potassium cyanide, Eden, Hampson, and Wheatland (213) found that the first product was always cyanogen chloride, which was rapidly hydrolyzed above pH 11 without further absorption of available chlorine. At lower pH values chlorine was absorbed up to a total of 5.75 g. atoms per g. mol of cyanide ion. At pH 11, zinc and cadmium cyanide complexes reacted with hypochlorites like potassium cyanide; cuprocyanide reacted rapidly with oxidation of copper to the cupric state, but nickelocyanide was attacked only slowly. They propose treating waste waters containing simple cyanides and/or zinc, copper, and cadmium complexes, with calcium hypochlorite at pH 11. The paper contains considerable experimental data. Pettet (470) also reports on a similar study with the same findings.

Kessler and Oyler (343) described the steps taken in a commercial plating plant to keep cyanides in process water below 2 p.p.m. These included installation of a reclaim tank; a separate system for collecting grease, oil, solvents, etc.; discontinuance of cyanide cleaners; and separate destruction

of strong cyanide wastes. Various changes in plant operation reduced the cyanide content of rinse waters. Reed (498) presented the operating details of a plating waste treatment employing continuous flow for weak, and batch operation for strong, wastes. Chromates are reduced with bisulfite and precipitated with lime; cyanides are destroyed with alkaline chlorine treatment; acid-oily wastes are skimmed in a sump and neutralized with lime. Effluents from these steps are given a final treatment in an Accelerator. Simpson and Thompson (556) gave cost and operating data on a disposal plant for a small plating operation. A survey halved the volume of waste water containing cyanides, but variability in composition dictated a batch process. The final plant is treating 3,200 g.p.d. of waste water with an average cyanide content of 0.288 lb. Construction cost was $8,250 and operating charges are estimated at $17 per month. Waite (632) concluded that the alkali-chlorine method was the best among available processes for destruction of cyanides on a continuous flow basis. Calise (154) described a plant costing $1,500 to $2,500 for treating wastes from a small plating shop.

The operating procedures at the Curtiss Wright cyanide waste treatment plant are described (24). The more popular alkaline chlorine treatment method is used on a batch basis. Careful control testing procedures are employed to insure a safe effluent. Of greater interest is the alkaline chlorine treatment of cyanide, containing rinse waters directly in the rinse tanks (27). Rinse waters are recirculated and caustic is continuously added to maintain a pH of 8.5 to 10, which is continuously indicated with an electric pH meter. Chlorine is continuously fed from gas machines by recirculating rinse water through the chlorine injector. Make-up water amounting to 1 g.p.m. is added and a like amount of cyanide-free waste is discharged to the sewer. An added advantage is the reported quality improvement in rinsed metal parts.

Corcoran (179) stated that it would be unwise to depend on acclimatization of sewage treatment processes to cyanides because of the time required and the danger of high concentration surges. He advocates plant surveys to reduce cyanide waste because this will reduce pollution more than any other measure. A gallon of plating solution must be diluted with 120,000 gal. of stream water to avoid fish killing. Ponding of cyanide wastes should be considered only a temporary expedient because of danger to humans and animals. The danger from acid treatment, plus aeration to vent hydrocyanic acid gas, is not great because workmen can withstand a concentration of 10 p.p.m. per 8-hr. day, as compared with a limit of 2 p.p.m. of chlorine. Complete oxidation of cyanides by alkali-chlorine method is recommended as the best treatment process. Ferrous sulfate and lime treatment is used abroad, but investigators in this country do not agree on the extent of cyanide reduction; although a cheap method, it has serious disadvantages. Dobson (200) reviewed the various methods for cyanide disposal and presented two schematic methods for cyanides and one for cyanides plus chromium. He also discussed analytical methods for cyanides.

Sierp and Ziegler (558)(559) contribute valuable information on the toxic effect of zinc salts to sewage treatment processes. They show that zinc concentrations should be below 5 p.p.m. in order not to interfere with biological treatment processes.

Three commercial plants for treating cleaning and plating wastes were described by Tarman and Priester (590). In each case the varieties of wastes were treated separately by a combination of pH adjustment, coagulation, and sedimentation; effluents from various steps were combined for final treatment. They also described

the solution of a cyanide pollution problem that arose at a manganese blast furnace. Substitution of dry gas cleaning for wet washers eliminated water containing cyanides. Previously, the washer water had been treated with ferrous sulfate to bind the cyanides as iron ferrocyanide, and the treated liquor was settled in lagoons. When the change was made to dry gas cleaning, the furnace cooling water (which contained no cyanides) continued to be discharged to the lagoons. The stream receiving the lagoon discharge contained cyanides, however, due to decomposition, by the action of sunlight, of ferrocyanides in the lagoons and pickup of cyanide by the cooling water. Installation of a cooling tower for the furnace water and abandonment of the lagoons eliminated the cyanide pollution. This paper contains considerable practical information.

Bloodgood and Strickland (120), recognizing that there is no practical method for removing chromium from dilute solutions, attempted to develop a method employing anion exchange resins. They found that chromium can be effectively removed from solution by this technique, but that there is no satisfactory procedure for regenerating the resin by a direct replacement reaction. In another paper (119) they discuss the low recoveries of chromium which led them to an extensive study of chromium chemistry. Olation, oxolation, and the coordination theory of Werner are discussed in some detail to provide a background. The strong tendency of chromium to form complexes, and the oxidation of chromate by exchange resins, suggested that success might be achieved with a reducing agent having no tendency to form anionic complexes with either trivalent chromium or chromate. An acid solution of hydrogen peroxide seemed to fit these conditions, and a number of cycles were run using acid peroxide and hydrochloric acid alone as regenerants. Regeneration with acid peroxide was much more rapid and gave more complete elution of chromium than hydrochloric acid alone, but peroxide regeneration was more effective if the resin was first rinsed with hydrochloric acid. This procedure gave 94 per cent recovery of chromium, and the resin retained 50 per cent of its original capacity after eight cycles. It is believed that improved recoveries and lower resin deterioration are possible with a better technique. Experimental studies are being continued. Selke and Bliss (552) developed the mechanism of resin exchange, determination of exchange rate, and the fundamental constants for cupric ion exchanged for hydrogen, magnesium, calcium, and sodium. Bed regeneration was not studied, but will be reported later. Two examples of the use of developed data in design are given.

The discharge of large volumes of industrial wastes containing cyanides to the West Middlesex sewer system has not caused any trouble with the operation of the Mogden treatment plant, England, according to Lockett and Griffiths (380), because of the large dilution. However, the discharge of 50,000 gal. of waste containing 20 p.p.m. of cyanide to a sewage flow of 1 m.g.d. would not be safe. Cyanides in some cases, when present in low concentrations in sewage, react with other substances, such as iron, and are destroyed. They may also be volatilized in sewers as hydrogen cyanide; but the possibility of oxidation to cyanates and formation of sulfocyanides in sewers is doubtful.

Concentration of cyanide in sewage should not exceed 10 p.p.m. from the standpoint of the safety of men working in sewers. Sewer ventilation cannot be relied on as a means of reducing the concentration of HCN in sewer air. Concentration of cyanide as low as 1.0 p.p.m. has a deleterious effect on biological purification processes.

In tests covering two years, Klassen, Hasfurther, and Young (347) found that 50 per cent of test fish (sunfish and bluegills) survived 30 days in

chromium concentrations as high as 49 p.p.m. in hard water. At this limit, examination of fish disclosed no unusual characteristics. At higher concentrations, however, fish that died showed deterioration, including discolored liver and ruptured spleen. A summary of each test is given. Miller (409) reported on 14 cases of fish killings due to discharge of cyanide plating waste. These accidents were caused by inadequate supervision, maintenance, and instructions to employees, as well as to inadequate storage and disposal facilities.

A bibliography of plating wastes, including pertinent references to pollution control and abatement and disposal of pickling liquors, was prepared by Dodge and Reams (202). The same authors (203) have written a critical review of the literature on disposal of waste cyanide solutions.

By-Product Coke Wastes

The Armco phenol recovery unit at Hamilton, Ohio, was described by Wilks *et al.* (644). Liquor from the free leg of the ammonia still is pumped to the top of a 4-section tower, in which the phenol is stripped by recirculated steam. Caustic soda solution is fed to the top of the third section, and dephenolized steam passes to the fourth section to strip more phenol, returning to the bottom section, where make-up steam is added. The sodium phenolate is sprung with blast furnace gas. The plant operates equally well with feeds up to 2,000 g.p.h. Carbone, in the same paper, stated that weak ammonia liquor from the Allied Chemical plant at Ironton, Ohio, is dephenolized in two countercurrent benzol extractors; the liquor and benzol are mixed in centrifugal pumps. The benzol-phenol is water-washed to remove CO_2 and H_2S. It is then washed with caustic soda solution to remove the phenol; the dephenolized benzol is returned to the extraction step. The sodium phenolate is heated and blown with steam to remove traces of light oil and naphthalene, then sprung with CO_2 and H_2S from the distillation of dephenolized weak liquor. Further refinement of the phenol layer, and return of phenol-containing washes for retreatment, results in recovery of 97 to 99 per cent of phenol as commercially pure product. Thompson said that the National Tube recovery plant at Lorain, Ohio, differs principally from the Allied Chemical plant in using a packed tower to absorb phenol from weak liquor. The average extraction, over a 20-year period, of phenol from a liquor containing 0.075 per cent by weight, has been 95.46 per cent. Operating details are given for each of the three installations.

Botley (126) reports that increased sale of gas in Britain has led to a greatly increased production of gas liquor, and many gas plants pay heavy charges to sewage authorities to dispose of it. Although ammonia recovery is not practical at the smaller plants, improvement of the disposal situation is possible by more careful control of scrubbers, condensers, and purification practice. Electrostatic detarring of gas results in a liquor of greatly reduced toxicity. It has been stated (55) that the best solution of the liquor disposal problem at gas works is to provide for uniform continuous discharge to a municipal sewer of liquor containing a minimum quantity of thiocyanate and polyhydric phenols, and from which ammonia, sulfides, and cyanides have been removed by distillation. A large number of processes are available for removing monohydric phenol, but these may not be profitable operations. One plant, which uses light creosote as a phenol solvent, is said to be operating profitably, but it was built before present high construction costs. Badger (100) (101) recommends distillation of ammonia and discharge of the still bottoms to the sewer.

The experimental treatment of waste gas liquor at the West Bromich, Eng-

land, sewage works is reported by Clifford (172). One plant trickling filter was converted to a recirculating filter. The filter could handle a C.O.D. loading of 2.5 times the normal with insignificant impairment of effluent quality, even though 60 per cent of the C.O.D. load was contributed by gas liquor.

The Royal Commission on Sewage Disposal suggests that sewage effluents contain a maximum of 20 p.p.m. B.O.D.; discharge of 0.25 per cent crude or 0.5 per cent spent liquor would meet this condition. Tests showed that phenol and catechol were oxidized easily, and some polyhydric phenols with difficulty, at sewage plants. A new process showing promise comprises benzol washing to remove 80 to 95 per cent of the phenol; distillation and concentration of spent liquor in a three-effect evaporator to yield 20 per cent ammonium chloride solution; washing of solution with phenolsolvan to remove polyhydric phenols; and crystallization of ammonium chloride. Thiocyanates and thiosulfates concentrate in the mother liquor and are removed by an anion exchange resin; the resin is regenerated with alkali. A formula for determining the sewage treatment charge for gas liquor is based on suspended solids, oxygen consumed from permanganate, and total nitrogen content. It is pointed out that gas liquor is 100 to 200 times as strong as sewage by the oxygen consumed test; 20 to 30 times by B.O.D.; and 200 to 400 times by total nitrogen. Thus, decision on a rational formula is difficult and awaits further research on actual strength in terms of sewage treatment costs. Priestley (487) reviewed current British disposal practice and discussed the constituents of gas liquor, giving oxygen consumed values for each. He reported that 40,000 g.p.d. of spent gas liquor had been handled on four 120-ft. trickling filters that had first been activated with dilute sewage, then given a gradually increasing dose of spent liquor until the filters were operating on gas liquor alone. This installation was said to have been abandoned because of high capital and operating costs.

Analytical procedures for phenol were discussed by Riehl and Will (508). They advocated the Gibbs-Sanchis method, as modified by Scott, for general use. The exact procedure in use in the Ohio Department of Health laboratories is given in detail.

Waste Pickle Liquor

A new process that uses waste pickle liquor to recover manganese from low-grade ores was described by Hoak and Coull (302). The process involves leaching the ore with the liquor; conversion of the sulfates in the extract to chlorides; differential precipitation of iron with limestone; and precipitation of the manganese with quicklime. The calcium chloride solution remaining is concentrated and returned to the chloride conversion step. The process yields a 60 per cent manganese concentrate from a 15 per cent ore, but its disadvantage lies in the distance from ore deposits to pickle liquor sources. Further development work is in progress. The process is patented to Hoak (303). Use of ion exchange to improve the economics of phosphoric acid pickling has been proposed by Paulson and Gilwood (465). Phosphoric acid is claimed to be superior to sulfuric acid for pickling, but it has not been widely used because of its high cost. A hydrogen zeolite can be used to recover phosphoric acid substantially completely from the spent pickle, and sulfuric acid is used as the regenerant. Such a process would leave an iron sulfate liquor for disposal. The authors do not consider this factor, but they say that phosphoric acid attacks the base metal less than sulfuric and thus imply less iron for disposal. Heide (288) has patented a process for making a fertilizer additive from pickle liquor by pouring molten blast furnace slag into the liquor to yield a dry, porous product. Tests have

shown that this material can eleminate the necessity for the usual fertilizer conditioners.

In a study of the Gehm upflow calcite filter, Eden and Truesdale (214) found that the limiting acid concentration for effective neutralization depends on the temperature of the solution. Sulfuric acid neutralization ranged from 9,880 p.p.m. at 60° C. to 436 p. p.m. at 30.4° C. Ferrous sulfate did not interfere with neutralization of acid, and iron was not precipitated in the bed. This procedure might be applicable to reduce acidity in waste water from steel mills, because large volumes could be treated in a relatively small plant. Lab (359) gave details of the construction and operation of a small pickle liquor neutralizing plant. An average of 650 lb. of dolomitic lime is used per 5,000-gal. batch. The economic and technical factors involved in selecting a neutralizing agent for pickle liquor were discussed in detail by Hoak (301), who also described an aeration-neutralization technique yielding a slurry that settles and filters very rapidly. Hedenstad (286) reported that control of pickle liquor discharges at Worcester, Mass., had improved trickling filter operation. Wing (650) described the pilot neutralization work carried out by his company. He concluded that no more than a 10 per cent excess of lime over the stoichiometric amount was required for pickle liquor neutralization; that it is desirable to slake lime with between 75–25 and 50–50 filtrate-fresh water mixtures, depending on strength of liquor, to reduce total volume and improve filtration rate; that it is desirable to treat the liquor hot to improve filtration rate and cake dryness; that quicklime can be slaked in the reactor; that the liquor should be pumped into the lime slurry; and that high-calcium lime should be used because of its rapid reaction rate. Reed (499) reviewed the more important processes that had been proposed for pickle liquor treatment. He concluded that these processes do not now, and probably never will, offer a general solution to the problem. Diligent study of certain processes should continue, but there is little likelihood of a startlingly new or profitable process being developed. The best possibilities lie in the direction of reducing or eliminating acid entirely.

Waste acid has been greatly reduced in volume by plant survey and process changes by the Tennessee Copper Company. Jones (334) states that improvements in roasting sulfide ores have reduced sulfur trioxide losses to 2 per cent from 6 per cent. Neutralization studies indicated that high-calcium lime would be too costly; through laboratory investigation a dolomitic limestone was found that was superior to some high-calcium stones. This is quite unusual; it was ascribed to an uncommon crystal structure. He found that the reaction rate was proportional to acid concentration, thus pointing to treatment of strong wastes. An excess of stone is required for complete neutralization. Lewis and Yost (375) reviewed the technical considerations in choosing an alkaline material to neutralize acid wastes. Their paper contains much practical advice on many factors, including cost of material, handling problems, methods of application, sludge formation, and the tendency of calcium sulfate to form supersaturated solutions. Dickerson and Brooks (199) described the design and operation of a plant to neutralize a combination of nitric and sulfuric acids that varied widely in ratio, volume, and strength. Dolomitic lime, used in a multi-unit reactor with pH control, gave satisfactory results.

Oil Field Brines

Methods used by the oil industry to dispose of brines by sub-surface injection were described by Cecil (164) who suggested applications for the chemical industry. He pointed out that the underground formation must be chosen to avoid pollution of fresh water; if it

contains salt water it is safe to assume that no future pollution problem will develop. Sufficient hydraulic pressure must be used to overcome the weight of earth above the well bottom and cause general fracture of the formation. There is a great variation in the amount of water that can be injected, ranging from several thousand g.p.m. with no surface pressure (cavernous limestone) to 100 g.p.m. at 2,000 p.s.i. (dense sandstones). The water must be treated to avoid plugging the formation or reaction with the water in the reservoir. This treatment may include removal of suspended solids by coagulation and filtration; stabilization to prevent scaling; corrosion control to prevent precipitation of metal hydrates; sterilization to prevent bacterial growths in the formation; and removal of salts that would react with water back of the formation. Details of each of these treatments are given. An interesting historical review of oil production was prepared by Morris (429), who reported data on brine production and recharge. The East Texas Salt Water Disposal Company was organized in 1938 by the oil producing interests to eliminate salt water pollution and to maintain pressure in the oil wells. The Railroad Commission of Texas fixed the water/oil ratio for producing wells and penalized operators who exceeded the ratio. The disposal company operates like a public utility, and is required to service all producing wells. Brines are carried from the wells to treatment plants in asbestos-cement pipes, and are injected after proper stabilization. This plant has worked very well. Not only has pollution been eliminated in this field, but injection of the brines has maintained bottom hole pressures and permitted many wells to flow that otherwise would have to be pumped.

Refinery Waste Disposal

The characteristics of oil-in-water emulsions were discussed by Milne (410), who noted that the emulsifying agent should be the point of attack in breaking emulsions. Although various means can be employed to form emulsions, only soaps are generally used. There are four classes of these soaps—sodium or potassium salts of fatty acids, amino salts of fatty acids, sulfated oils, and sulfonated aliphatics or aromatics. Sodium soaps are usually favored among these types. Chemical methods are more satisfactory than others for breaking emulsions; they include reaction with polyvalent salts, salting out, and breaking films with acids, ethers, etc. Polyvalent metal salts often present the easiest and most convenient method. Calcium or magnesium salts will break emulsions, but they sometimes cause reversion to the water-in-oil type. Proctor (489) reported that a separate plant was built to treat emulsified oils when they upset the operation of an A.P.I. separator. The emulsions first flow to a sump, from which up to 200 bbl. of oil is skimmed daily. The effluent (175 p.p.m. oil) is treated with lime and ferrisul (3 grains per gal.) in a flocculation tank and then flows to a 60-ft. clarifier, which produces a sparkling effluent containing less than 2 p.p.m. of oil. Miller (404) described the operation of an A.P.I. separator, which includes, as an unusual feature, a coalescer between the preliminary sump and the separator. The coalescer consists of a 3.5-ft. depth of graded stone and sand; water from the preliminary sump enters through a spider on the bottom and discharges from the top. The coalescer breaks globs and coalesces minute oil particles, making them amenable to removal in the oil-water separator, which follows the A.P.I. design closely. An increase in the inlet chamber to an A.P.I. separator to provide a 5-min. detention improved the operation markedly, according to Baum (108), who stated that 95 per cent of the oil and 85 per cent of the sludge are removed in this chamber. Design data are given. Small (562) described

a self-adjusting skimmer for oil-water separators. It comprises a rectangular floating metal box equipped with a weir and a buoyant chamber so related that the weir always finds its own level for proper skimming, regardless of the quantity of oil in the box. Oil is removed from the box at intervals, through a suction pipe. The device reduces the man-hours required by conventional-type skimmers, which need constant manual adjustment; it minimizes fire hazards; and lessens evaporation losses. A patent has been applied for by the Standard Oil Development Company.

Rohlich and Ingersoll (517) report the results of a laboratory study on gravity oil separators. The problem of evaluating flow distribution and short circuiting was studied by quickly adding small amounts of trisodium phosphate and determining the phosphates colorimetrically, using a spectrophotometer. This allows a precise phosphate determination to be made and eliminates change in flow characteristics because of an appreciable change in density of the water.

A pilot plant for treating 850,000 g.p.d. of waste water containing sulfonated alkyl aromatic compounds was described by Schindler (540). The pH is adjusted to 5, then lime is added to pH 8 and the mixture allowed to settle. If decolorization and settling are poor, the pH is raised to 10 and ferrous sulfate is added. The plant reduces color to 150 p.p.m. from 10,000; oxygen consumed to 63 from 537; oil to 54 from 5,480. Walker (633) discussed a two-stage acid-alkali process for treating a complex mixture of waste soluble, lubricating, and cutting oils running 2,000 to 4,000 p.p.m. oil. Alum (1 to 2 lb. per 1,000 gal.) is added in the first (conditioning) stage; oil separation is not an object in this step, but any oil released is skimmed to prevent interference in the second step. Lime (1.5 to 2.5 lb. per 1,000 gal.) or sodium hydroxide (4.6 lb. per 1,000 gal.) is added in the second stage to precipitate suspended and oily matter. At one plant using caustic in the second stage the sludge is treated with sulfuric acid (4.2 lb. per 1,000 gal.) to recover alum for re-use, because no lagoon space is available. Precise control of the process is not necessary. Fowler (236) described the pollution abatement program at a refinery which included segregation and reduction of waste water volumes, and installation of oil separation equipment. Details of equipment design and operation are given. Weston (641) (642) presented detailed reviews of refinery oil separation problems. He introduced the susceptibility-to-separation (S.T.S.) concept to measure the amenability of oil to gravity separation. The S.T.S. value of oily waste water is equal to the oil concentration in p.p.m. in the middle layer of a settled sample. Typical S.T.S. data are tabulated, and the characteristics of various wastes are described.

The American Development Corporation (67) has introduced an electrolytic method for treating spent caustic solutions. Spent caustic from the gasoline scrubbing tower is settled to remove entrained hydrocarbons, then passes through an electrolytic cell containing electrodes separated by membranes permeable to liquid but not to gas. The liberated hydrogen is drawn off, and the nascent oxygen oxidizes the mercaptans to disulfides insoluble in caustic solution. The sulfides separate as an oily layer. Brown and Kurtis (133) described a process for treating spent caustic with carbon dioxide. Although CO_2 treatment of this waste has long been known, it has not been practical for refinery use because of the difficulty of compressing stack gases. The flue gas from catalytic crackers now supplies CO_2 at 15 to 20 p.s.i. The spent solution is fed to the top of a tower containing 10 perforated contact trays and the flue gas is introduced at the bottom. The caustic solution is recirculated in the tower until neutralization is complete. The top gas from the tower passes through a

disengaging drum, thence to a firebox where the sulfur compounds are burned.

The Ohio River Valley Water Sanitation Commission has published a booklet (65) outlining general practice for handling breaks in oil pipelines and discussing precautions that should be taken to prevent such emergencies.

Miscellaneous

Gutzeit (274) has described a tank car cleaning plant being built at Saegertown, Pa. Tank car wastes are a complex mixture of many widely different products and the principal treatment problem involves collecting similar wastes for treatment together. A novel feature of the new plant will be the use of fine coal to remove hydrophobic matter from the waste water. The wastes contain their own collecting agents (phenols, fatty acids, and many polar and non-polar organic compounds), and it is only necessary to disperse the coal and aerate to produce a foam containing the adsorbed matter; the foam is scraped to a launder for disposal. Where coolant emulsions are reclaimed for re-use, the hazard of infection of workers must be recognized, according to Pratt (486). Burlap bags were formerly used at a large ballbearing plant. Although these worked well enough, dermatitis was frequently serious among the operators of the system. Vacuum spring filters were tried, but dermatitis increased as a result of bacterial growths. Finally, a froth flotation process was adopted, whereby rotors beat the coolant to a froth, which permits skimming the floated impurities. Health hazards have been greatly reduced by this method, which yields a satisfactory coolant for return to the machines. Kohlins and Demarest (352) presented cost data on a plant designed to evaporate plating wastes. One m.g.d. acidic solution containing copper, zinc, and cadmium is mixed with alkaline waste containing cyanides to yield a neutral solution. This mixture is reduced to 7,500 gal. in a 5-effect evaporator and the concentrate is shipped to a refiner for recovery of metals. The installed cost of major equipment items was $380,000; the total operating cost, including interest and depreciation, is 15.6¢ per gallon of feed.

Wastes containing cutting oils from airplane engine manufacturing are discussed by Hogg, Pettet, and Collett (305). The remedy consists of oil collection, chemical treatment, and installation of interceptor equipment.

Waste Gases

Sittenfield (557) presented a general paper on the treatment and disposal of industrial gases. This is perhaps the first time in this country that aerial pollution problems have been discussed at a meeting heretofore devoted entirely to liquid industrial wastes. Because many of the factors involved in the solution of aerial and liquid waste problems are similar, the disposal of gaseous and liquid industrial wastes should be more closely allied.

Sugar Beet Wastes

A successful method of chemical treatment for sugar beet process water from the pulping operation is given by Pearson and Sawyer (466)(467). The method consists of heavy chlorination at controlled pH values, followed by lime treatment, coagulation, and settling. Sludge is lagooned, the effluent being returned to the extraction batteries. Improved sugar yield, elimination of fermentation in batteries, and adaptability to seasonal operation are some of the advantages claimed.

Rice

Rice processing wastes were studied in the laboratory by Heukelekian (294). The waste organic matter consisted mainly of starch and was deficient in nitrogen. Plain sedimentation removed 29 per cent of the B.O.D., while 2,000 p.p.m. of lime removed 60

per cent. Digestion after nitrogen supplementation with ammonia gave 92 per cent B.O.D. reduction in 1.2 days with a 0.1 lb. B.O.D. per cu. ft. loading. Aeration for 24 hr., using dispersed biological growths and ammonia addition, produced an effluent of 25 to 50 p.p.m. B.O.D. and reductions as high as 95 per cent.

Glass

The treatment of an abrasive waste from plate glass polishing is described by Oesterle (446). The article is particularly interesting, because the problem involved pumping of an abrasive suspension containing powdered glass, silica, emery, rouge, plaster of paris, and powdered iron.

Coal Washing Wastes

An article by Rickert and Bishop (507) deals mainly with the operation of a coal recovery plant using a froth flotation process. Subsequent settling of the flotation cell tailings in a standard thickener is briefly mentioned. For those interested in coal washing wastes, the U. S. Bureau of Mines has published a list (142) of their publications on the subject.

Flotation

A description of a new flotation unit is given by Gibbs (255)(256). The flotation cell is a circular steel tank with a peripheral overflow weir. A scum baffle extends almost to the bottom, so that effluent is taken from that point. In order to produce small bubbles for efficient flotation, air is admitted into the suction side of a centrifugal pump recirculating line. The recirculated flow is distributed near the bottom of the tank and the released bubbles carry solids to the surface, where they are automatically removed by a revolving scraper. High solids removal was obtained with the first full-scale unit treating soap manufacturing wastes. The soap wastes were first treated with lime to precipitate calcium salts of the fatty acids, which are readily removed by flotation methods.

Preliminary tests produced good results with paper and wool scouring wastes, the solids of which have been proved amenable to removal by flotation.

WATER POLLUTION

Abatement and Control

A National Technical Task Committee on Industrial Wastes, sponsored by the U. S. Public Health Service and the Water Pollution Control Advisory Board, was established (37). It consists of about 30 members, with some 250 technicians forming the working committees (43). Immediate tasks of the Committee are: (a) assembly of source list of existing treatment and control practices, (b) listing existing research activities on industrial wastes, and (c) enumerating problems in treatment of industrial wastes (82).

Consideration is being given to amending the Water Pollution Control Act (P.L. 845) to: (a) increase the loan provisions to $5,000,000 for individual projects, (b) reduce interest rates on loans from two to one per cent, and (c) increase annual total loan appropriations from $22,500,000 to $50,000,000. A separate bill by Senator Byrnes would allow income tax deductions for amounts paid for industrial waste treatment work on a five year depreciation basis (43).

The Engineers Joint Council formed a task committee to establish a national water policy to aid the President's Temporary Water Resources Commission (71). The coordinating committee recommended greatly reduced federal spending on water resources development and would limit federal projects to those that are self-liquidating and self-supporting. On stream pollution the committee recommended that federal participation be limited to administration of existing laws (29) and to the research and guid-

ance upon which sound local laws may be based.

In the dispute of education *vs.* enforcement in securing pollution abatement, the former was more widely advocated (83). The Public Health Service was quite active in this field, preparing and distributing two booklets: one, for the general public, entitled "Clean Water is Everybody's Business" (491); the other, for professional personnel, named "Guide to Source Material on Water Pollution Control" (490). Water pollution reports on the 16 major drainage basins, which include the entire United States, are essentially complete at the present time (46). These will be summarized into a national report. The research program in water pollution has also been expanded. Wright (658) states that studies are being conducted at Denver and by three universities on pollution of irrigation waters. One editorial (40) expresses concern about the undermining of states' rights by Public Health Service action; however, P.L. 845 itself requires that no federal enforcement action may be taken without the request or consent of the authorities of the states involved and many articles indicate the extremely close liaison between federal and state agencies (491) (368).

In implementing the water Pollution Control Act (Public Law 845), Congress appropriated (176) the following amounts for fiscal year 1951: $750,000 for grants to states, municipalities, or interstate agencies for planning; $1,000,000 for allotment to states for investigation, research, and surveys; $1,500,000 for Public Health Service water pollution control activities; $1,400,000 plus contract authorization for $2,400,000 for a new Public Health Service building at Cincinnati, Ohio, for research, training, and studies of water pollution.

Interest-free loans totaling about $2,000,000 to 105 communities in the Ohio Valley for advance planning of sewerage facilities were reported (33), but total figures for the United States were not available.

In England, the Ministry of Health recommended passage of a new act to control pollution to replace the Rivers Pollution Act of 1870, but including provisions of the Salmon and Freshwater Fisheries Act of 1923 (75).

An editor's annual report (40) indicates that more success in stream pollution abatement will be attained with industries than with municipalities and stresses that municipal sewage treatment is a more important problem than industrial wastes. Municipalities, however, have already gone a long way, whereas industries, discharging several times the volume and strength of wastes discharged from municipal sewers, have a far greater task ahead of them. In general, the interstate agencies are considering water pollution and its control on a more realistic basis than previously. Most of them now consider each stretch of stream as an individual problem, there being certain amounts and types of waste that the stream can handle by self-purification without damage. Consideration of water uses below points of discharge and the establishment of attainable standards of water quality, followed by transposition to effluent qualities at each location, provides the most effective approach.

In an AWWA Committee Report (15), a compilation of interstate compacts and commissions is presented. There are now 15 Congress-approved commissions and four informal agreements and agencies of which 33 states are members. Most of the compacts in the West deal with division of irrigation waters and Colorado belongs to eight such groups. In the East they are largely for pollution abatement, with New York acting in four compacts. A tabulation of basic laws on pollution, by states, is also given (15). On surface waters, 29 states have agencies exercising some control, six have agencies with advisory powers only, and 13 have none.

Cleary (170) states that the Ohio River Valley Water Sanitation Commission now has a budget of $100,000. The Commission is meeting with representatives of each of several industries to pool resources and expedite water pollution control (39). Only 11 per cent of the cities over 5,000 population in the eight states signatory to the compact, have taken no action relative to providing sewage treatment (80).

The Interstate Commission on the Potomac River Basin expected a 1950 budget of about $38,000 (69). The Commission is concentrating on the important problems around Washington, D. C., which has started expansions to cost an ultimate $11,500,000. Other communities in the area are planning enlarged or new plants.

Progress was temporarily handicapped by the State Auditor of West Virginia, who withheld funds for the Ohio River Valley Commission (72). Stillerman (573) states that the California and Indiana programs are also stymied by legal hurdles. A New Jersey court ruled legal the use of local authorities and sale of revenue bonds to construct sewerage works (50); however, an Indiana court ruled that such authorities were not legal and construction work is stopped pending a State Supreme Court ruling (573).

Kentucky legislation established a Water Pollution Control Commission with six members, giving it authority to establish water quality standards according to use and to issue abatement orders (48). New or strengthened pollution control legislation was provided during the 1949 legislative sessions in: Delaware, Indiana, Iowa, Illinois, Michigan, Ohio, South Dakota, Tennessee, and Wisconsin (76) (78).

The Detroit Regional Planning Commission (49), the California Water Pollution Control Board (44), the New York State Joint Legislative Committee (77), the Maryland Water Pollution Control Commission (394), and several others have proposed tentative standards for water quality on the basis of usage. A court case, based on the 1947 Maryland Law, resulted in an injunction against a sand and gravel company, which was discharging 80 tons of solids per 8-hr. day (394).

At a meeting of the Governor's Council in October, the Public Health Service presented a model act to assist in the establishment of uniform state laws on stream pollution. This act was prepared in close cooperation with state health departments and water pollution control boards, and was endorsed by the Council of State Governments (492). The Federation of Sewage and Industrial Wastes Associations gave its program designed to stimulate immediate nation-wide steps to curtail stream pollution (74).

Stimulus since World War II has resulted in the completion of many municipal and district sewerage plans, quite a few of which were placed under construction in 1950 (32) (31) (30) (70) (356) (231) (342). Contracts for public sewerage construction for the year amounted to $287,400,000. This represents an increase of 4 per cent over 1949, as compared to an average increase of 32 per cent for all types of public construction (54).

A new term for waste treatment has been coined in California—water reclamation plants (287). Sewage must all be treated to a pre-determined degree and the effluent is then discharged to recharge ground waters through stream channels or percolation beds. Rawn (497) reports that about 6 acres per m.g.d. of initial flow of treated effluent is required for San Gabriel Valley spreading grounds.

A liberal policy of accepting industrial wastes has been announced by Laboon (360) of the Allegheny County Sanitary Authority. Acid mine drainage continues to be the major problem in the Ohio Valley, with an estimated 2,500,000 tons of acid yearly reaching the Ohio River (51).

The State of Washington set forth

procedures for inplant prevention and reduction of industrial waste discharges for various types of industries (634). These methods are effective and frequently are as important as the waste treatment plant itself. Fifteen pulp and paper mills in Washington, Wisconsin, and Oregon were ordered to reduce pollution (35)(36). The magnesium oxide process was proposed by one plant where pulp wood is floated in fresh water, but would not be satisfactory for wood floated in salt water (66). Oregon State College engineers recommended treatment of sulfite liquors by lagooning during the low-water period as the only feasible method (38). Murdock (435) suggests that Tyler's proposal of 1942 (the installation of aerators in streams) be considered where an excess of oxidizable matter is present, as from sulfite pulp plants. It appears that if such treatment is successful in streams, it would be more economical in municipal sewage or industrial waste treatment plants where the wastes are less dilute. Oesterle (447) describes a method of pumping abrasive wastes from a glass plant to a natural basin for thickening to eliminate the flow directly to the river.

The biggest problem in the pebble phosphate industry, as described by Fuller (242), is silt, which affects fish food and bottom life. The University of Florida is investigating lime precipitation of colloidal substances in the mine waters.

Bacteriology

Wolman (656) discussed the diversity of standards which exist for stream quality solely from a bacterial content. It was pointed out that the application of standards of fresh waters to sea water must be critically observed and questioned. Consideration must be given to the economic factors involved in the community in the use of judgment standards.

Vaccaro *et al.* (613) carried out laboratory experiments to determine why *E. coli* was unable to survive in sea water. After study of seasonal effects and methods of sterilization, the authors suggest that the bactericidal action of sea water may be due to an antibiotic action of the natural marine flora.

Williams and English (647) have shown that 127 of 365 coliform strains studied were able to produce demonstrable amounts of phenol when grown in casein digest medium. Of the strains 123 were citrate negative *Escherichia* and four were *Aerobacter*. Lieb (376) concluded from his studies that phenol decomposing bacteria at 22° C. were present in the mud of river banks, but not in the water.

Colmer *et al.* (175) have repeatedly isolated from acid mine drainage a bacterium closely resembling those displayed by the genus *Thiobacillus*. The bacterium rapidly oxidized the ferrous iron of such drainage to the ferric state. However, the mechanism responsible for the oxidation in either natural or artificial acid mine waters was not determined.

Hart (278) found that bacterial count was not a good indicator of industrial pollution, nor was any single organism of value.

Gray and Smith (268) have described a motile rod-shaped organism, which on nitrogen-free media fixed appreciable quantities of nitrogen gas. The bacterium was isolated in pure culture from three chalk streams near Cambridge, England. Growth was promoted by sugars and nitrate was rapidly reduced.

Vaughn *et al.* (621) reported that the growth and development of turbidity in Koser's citrate medium by *E. coli*, *E. acidilacti*, *E. communior*, and *E. neapolitana* was dependent on certain supplementary compounds, such as acetate, lactate, propionate, glucose, fructose, l-asparagine, and glutamic acid. The citrate in Koser's medium was utilized when the concentration of the supplementary compounds reached 0.1 to 0.5 per cent.

Studies were made directly on river water by Viehl (627) regarding the bacterial relationship and the complexities involved in the natural purification. More bacteria were present in the river water in winter than in summer, thus tending to balance the lowered activity. The effect of temperature on the rate of organic decomposition in river water and sewage was, therefore, less than would be expected.

Chambers (166) attempted to determine the number of coliform bacteria necessary for visible gas production in lactose-containing broth. Results from 780 determinations indicated a range of coliform population from 40,000,000 to 390,000,000 per ml., with an arithmetic mean and median of about 170,000,000 per ml. Production of a small bubble most frequently required at least 75,000,000 organisms. Gas production in lactose was obtained with 40 per cent lower population than in 2 per cent brilliant-green bile broth.

Pramer *et al.* (484) described a method for enumeration of tubercle bacilli, consisting of heating the sample at 50° C. for 30 min., and cultivating on Dubo's agar, to which 5 units per ml. of penicillin and 50 units per ml. of grisein have been added. Application of this method in the laboratory and in a preliminary plant survey indicated the following treatments effective for removal of tuberculosis organisms:

1. Coagulation with $FeCl_3$, followed by settling.
2. Continuous filtration through sand at a 0.24-m.g.a.d. rate.
3. Chlorination to a residual of at least 0.9 p.p.m. free chlorine.

Kruse (358) described a simplified technique to determine the presence of *E. coli* in drinking water. Varying quantities of water were drawn through membrane filters, which were cultured at 46° C. and 41° C. *E. coli* of human or warm-blooded animal origin will grow at both temperatures, whereas those from cold-blooded animals will not grow at 46° C. and were markedly inhibited at 41° C.

Mueller (433) established a quick test for coli determinations in fecally polluted drinking water by use of the membrane filter technique combined with a test for indol formation in tryptose broth. A positive result could be read after 3 to 8 hr. and the presence of *E. coli* demonstrated.

The work of Sears *et al.* (549) on the persistence of *E. coli* strains in the human intestinal tract recorded information which may be of use in anticipating the organisms to be found in streams receiving pollution from such sources.

Biology

Patrick (463) (464) believes that a great many species of the various aquatic plants and animals are present in healthy streams, but no single group is represented by a great number of individuals. A moderately toxic pollutant would result in a reduction of the number of species in the stream and a greater abundance of the individuals of the remaining tolerant species because of the decrease in biological competition. Very toxic wastes kill all organisms. In only a few cases, however, were species found that only occurred under a given degree of pollution and could thus be truly regarded as pollution indicators.

Biological measures of stream quality are useful for several reasons:

1. The physiological activities of aquatic organisms are essential to the maintenance of healthy water conditions. Therefore, direct measurement of biological life indicates the quality of the stream.
2. Chemical and physical characteristics of healthy streams vary widely and cannot be reduced to simple standards. No means are available for testing all toxic agents.
3. Attached organisms of the stream reflect conditions over extended periods of time, whereas chemical and physical

data from water samples indicate only conditions at the moment taken.

Van Horn (614) stated that both field and laboratory studies are necessary to evaluate biological indices of stream pollution. Bottom living plants and animals, as well as the fish and plankton, are useful indicators of the degree and type of pollution. Laboratory bio-assays with fish and *Daphnia* aid in the studies of toxic industrial wastes. In the final analysis, abatement of pollution must be evaluated and confirmed by the biologist.

Two valuable reviews on the toxicity of various substances to aquatic life were prepared by Doudoroff and Katz (204) and by Rudolfs *et al.* (524). Doudoroff and Katz (204) reviewed the literature on the toxic effects of alkalies, acids, carbon dioxide, carbon monoxide, chlorine, chloramines, cyanogen chloride, hydrogen sulfide, sulfur dioxide, and abnormally high oxygen tension to fishes. Rudolfs *et al.* (524) reviewed the literature on the effects of toxic materials on the microflora and microfauna of streams. The effects of enriching materials, which cause the eutrophication of lakes, are discussed. Certain undesirable plankton forms become more abundant in eutrophic bodies of water and the more desirable forms disappear.

A fish kill in waters containing ferro- and ferricyanides at concentrations far below those generally accepted as non-lethal was shown by Burdick and Lipschuetz (141) to be due to the decomposition and release of the cyanide ion from these substances. Experimental data place the toxic level of these compounds under similar levels of light intensity at a concentration between 1 and 2 p.p.m. Rapid development of toxicity has been demonstrated at a concentration of 2 p.p.m. of either potassium ferro- or ferricyanide.

Milne (411) believes that bio-assay of cyanide wastes in strongly aerated aquaria often gives misleading results. When bio-assays of cyanide solutions are carried on in waters of a high bicarbonate content, a buffered solution in the neutral pH zone results. Free HCN and some cyanide ion are formed and, therefore, HCN and not merely the cyanide ion is being tested. Continuous aeration results in the constant loss of HCN and a continued hydrolysis of the remaining cyanide solution. In bio-assays, replacement of the lost acid should be standard procedure in order to yield valid results.

Milne (412) found that goldfish were not harmed in a solution of nickelocyanide prepared by adding nickel sulfate to a solution of sodium cyanide. The nickelocyanide complex could easily be dissociated by strong acids into HCN, hence should not be discharged into extremely acid waters. It can also be decomposed by chlorine to give toxic cyanogen chloride.

Corcoran (179) stated that 49 per cent of fish kills by industrial wastes during a three-year period in Michigan was attributed to cyanide. It appears that as little as 0.1 p.p.m. CN is generally fatal to fish.

Brockway (130) believes that the ammonia content of waters in fish cultural establishments should be controlled. As the ammonia content of the water rises, the fish lose their ability to use oxygen. At 1 p.p.m. ammonia, the oxygen content of the fish blood decreases to about one-seventh its normal value and the carbon dioxide of the blood increases to about 15 per cent.

Castillon and Altschul (163) combined gossypol with proteins, amino acids, and carbohydrates. Gossypol itself was non-toxic to goldfish, but the water-soluble products of the combination were toxic in concentrations of 10 p.p.m. The separated pigment glands of cottonseed were significantly less toxic to fish than were the gossypol combination products.

Experiments with fish by Minkina (414) showed concentrations of more than 0.02 p.p.m. Fe and more than

0.5 p.p.m. Al are lethal to fish. On the other hand, a concentration of 0.1 p.p.m. Fe or 0.25 p.p.m. Al stimulates growth. Small amounts of Fe (0.1 p. p.m.) in a medium of pH 6 inhibits growth, whereas 0.01 p.p.m. Fe in a pH of 7.5 stimulates fish growth.

Erichsen and Naemerrer (220) reported a fish and plankton kill by $Fe(OH)_3$. Brown coal sludge adsorbed the $Fe(OH)_3$ so that the water was no longer toxic to fish. Fuller (242) found that top minnows and bream are not killed in waters taken from settling basins used to remove the semi-colloidal wastes resulting from pebble phosphate mining operations. Flotation chemicals, particularly tall oil in heavy concentrations, are lethal to fish and should not be poured directly into the stream. Effluents from the silting basins are non-toxic.

Brown and Kurtis (133) reported that spent caustic soda solutions from petroleum refineries containing phenolic substances and sulfides are toxic to fish and also have a high oxygen demand.

Trinitrotoluene was found by Seifert (551) to be toxic to fish at a concentration of 2.0 mg. per l. and hexanitrodiphenylamine is toxic at 0.15 mg. per l.

A heavy fish kill reported by Sorenson (566) was traced to waste water from a laundry. There was no significant oxygen depletion and the fish kill was believed to be due to toxicants used in chemical cleaning or to some poisonous substances washed out of the clothes. Microfauna, especially rotifers, were also killed, but the microflora were not markedly affected.

Sewage pollution was found by Connell and Cross (177) to favor the growth of *Gonyaulax* in Offat Bayou, near Galveston, Tex. Fish kills follow the occurrence of the red water organism. High B.O.D. and consequent anaerobic conditions were attributable to the *Gonyaulax* bloom and were important contributing causes to the mass mortality in this region.

It has been suggested that the pebble phosphate industry effluent has added to the phosphate content of the sea water, thus contributing to the growth of the red tide organisms. Fuller (242) states that these discharges are not great enough to raise the phosphate content in the large areas of the sea in which the red tide was observed.

Cross (183) found that raw sewage had apparently benefited the fish of Stillwater Creek, Okla., for the abundance of fish is now greater than found in previous surveys. Sludge deposition in the stream bed has increased, however. Some of the increase in fish production may be due, however, to the regulation of stream flow because of the presence of impounding reservoirs.

Fish and Rucker (229) found that the B.O.D. load of the Williamette River and its tributaries reduces the dissolved oxygen of this river to create a pollutional barrier to important salmon runs. Laythe (367) states that the acute pollution of this river has eliminated the important summer runs into the river. Removal of the pollutional barrier would increase the valuable salmon run in the Williamette to five times its present size.

Liebmann (377) reported that wastes from the wood sugar industry contain furfural, resins, tannin, and acids, and sometimes soda, calcium, hydroxide, ammonium fluoride, and disinfectants. Wastes were fairly toxic to fish and had a high oxygen demand. Sludge banks are deposited and growth of *Sphaerotilus* is encouraged.

Lawrence (366) determined the toxic concentration of the commercial insecticides, DDT, methoxychlor, toxaphene, chlordane, and B.H.C., to common food fish in aquaria and earthen ponds. Pagan and Hageman (451) used guppies to test for the DDT residues on agricultural products.

Tarzwell (591) studied the effect on fishes and other aquatic life of the routine manual and airplane application of DDT, DDD, chlordane, and toxa-

phene. Many crustacea were more sensitive than fish. The solvent, type of water, pond vegetation, silt, or turbidity all effect the toxicity of DDT to fish; fish were found to vary in their sensitivity to DDT.

A major fish kill due to chlordane was reported near Waterloo, Iowa, by Morgan (428). This insecticide, which experiments showed to be toxic at 0.5 p.p.m., was accidentally poured into the city sewers and killed fish in the receiving stream. Addison (5) reported that an accidental discharge of toxic substances from an antiseptic manufacturing plant caused a heavy fish kill. Chemical and biological examination of another lake showed fish were destroyed as a result of highly alkaline conditions combined with excess oxygen in the water.

Van Horn, Anderson, and Katz (618) showed by bio-assay methods that the sulfides, mercaptans, resin acid soaps, and sodium hydroxide in kraft pulp mill wastes are most toxic to fish, crustacea, and aquatic insects. Under efficient operation, the loss of these compounds to the receiving stream can be restricted to non-toxic levels. Hasler and Wisby (283) showed that under laboratory conditions minnows could be trained to detect phenols in concentrations as low as 0.5 p.p.b. They also could be trained to distinguish between phenol, ortho-chlorophenol, and para-chlorophenol.

MacKenzie (391) reported that studies by the Biology Section, Environmental Health Center, Public Health Service, are being directed to the development of standardized techniques for routine bio-assays of industrial wastes that are troublesome because of volatility and high oxygen demand.

Daphnia are sensitive to the same toxicants as fish, according to Riemann (510). Substances that kill *Daphnia* in 24 hr. or less are also toxic to fish. The author suggests *Daphnia* as a substitute for fish in bio-assay procedures.

Anderson (16) determined the apparent threshold concentrations of toxicity to *Daphnia* of 25 cations. They found in general that *Daphnia* and related forms are more sensitive to cations than are fish. Copper, silver, mercury, and cadmium were found to be among the more toxic cations.

Hunter (320) subjected *Marinogammarus* to various doses of mercuric chloride and copper sulfate and measured the toxicity by changes in the animal's activity. Copper interferes with the respiration and the osmo-regulatory system; mercury acts by direct and general poisoning of the protoplasm.

Chamberlain (165) surveyed the literature on the growth, occurrence, and control of algae in water supplies; listed the algal groups known to produce tastes and odors; and investigated the role of algae in the precipitation of calcium and magnesium salts in relation to their effect on water filtration. The *Myxophyceae* and *Diatomales* are the principal taste and odor producers.

Rodhe (515) made an extensive and thorough study of the environmental requirements of fresh-water plankton algae. Among the subjects studied were the determination of growth and chlorophyll content in pure cultures of plankton algae, photometric determinations of iron concentrations in synthetic solutions and lake water, the source of iron in nutrient solutions, a nutrient solution for autotrophic plankton algae, phosphate as a growth factor, the influence of nitrate deficiency on growth and chlorophyll formation, iron as a limiting factor for growth, influence of magnesium and potassium deficiency on algae growth and temperature, and light as factors for the growth and annual periodicity of plankton algae.

Butcher (149) reported that even in unpolluted streams algae present at the source of a stream are replaced by a different biological community downstream because of the progressive increase of mineral salts due to natural drainage. In grossly polluted streams large numbers of *Stigeoclonium* first

develop; this is then replaced by *Nitzchia* and *Gomphonema*. Finally the *Cocconeis-Chaemisophon* community develops.

Spencer's (568) study of a Massachusetts reservoir correlated the numbers of phytoplankton with dissolved oxygen, carbon dioxide, water temperature, sunlight, pH, soluble silicates, and the manganese content of the water. Water temperatures and hours of sunlight affected the abundance of some forms, but did not account for the major pulses. Plankton pulses were accompanied by an increase in dissolved oxygen and pH and by a decrease in free CO_2. Silica was considered a limiting factor in the production of *Bacillariophyceae*, but did not affect the other classes. Manganese was absent from the epilimnion at all times.

A year-long study of the ecology and annual changes of the plankton in the River Hooghly was made by Roy (520). Variations in the numbers of phytoplankton, particularly diatoms, are responsible for annual variation in the yield of plankton. Fjeringstad (230) made a study of the microflora of the River Molleaa and related the benthoalgae forms with pollution.

Stone and Abbott (574) found that sewage placed in troughs develops a green growth that does not settle out. Green organisms replace the original suspended solids. Their respiratory synthesis results in an increase in B. O.D. The authors developed a method of evaluating the photosynthetic factor of samples by determining the dissolved oxygen of samples incubated in the dark and exposed to light. Lord (381) reports that the modern activated sludge plant at Madison, Wis., produces an excellent effluent, which is high in inorganic nitrogen and phosphates. The receiving lakes are enriched thereby, resulting in excess algal blooms, which in time decay, causing a pronounced odor nuisance.

Heusden (295) reports that the water supply of Amsterdam is heavily polluted and is allowed to self-purify by retention for 30 days in flow-through reservoirs. High concentration of nutrients results in blooms. From 0.12 to 0.25 mg. of ferric chloride per liter and 30 to 60 mg. of aluminum sulfate per liter adsorb the phosphate on the floc of the ferric and aluminum hydroxides. Plankton completely extracted the nitrates from the water, and the phosphates to a large extent.

Buffle (139) discusses the effect of plankton in lake water in relation to its use as a source of supply and describes processes for the removal of plankton by sedimentation, chemical treatment, exposure to light, and filtration.

Lovett and Brown (384) reported a fish kill in a shallow lake that had had a profuse growth of algae, which caused an oxygen supersaturation and a pH of 9.5 to 9.6 in the water. The authors feel that the fish were killed by either the development of a high caustic alkalinity or the effects of supersaturation of oxygen, or a combination of both. Brown (132) found that in a lake of hard water and an initial pH of 8.1, *Vaucheria*, *Spirogyra*, and *Zygnema* were killed by 10 p.p.m. copper sulfate. *Elodea*, *Hippuris*, *Myriophyllium*, and *Utricularia* were unaffected by this dosage. From 6 to 10 p.p.m. of sodium arsenite destroyed all of the higher plants except *Utricularia*, but stimulated algae and fungi. At this concentration, arsenic was not toxic to fish and tadpoles.

Only *Peridinium* and *Diaptomus*, which were in the upper oxygenated layer of a lake, were found by Atkin (95) to cause trouble by clogging filters. In the oxygen depleted lower layer, blue-green algae have developed abundantly. A heavy rainfall causing an influx of cold water into reservoirs forced the layer containing *Oscillatoria* to the surface, resulting in a marked increase in color and taste of water.

Swartz (581) describes a method of enumeration of algae and discusses some taste and odor effects of certain

algae. A chart is presented showing common algae found in water supplies.

Silvey *et al.* (560) review the relationships of *Actinomycetes* to taste and odor in water supplies and recommend methods of control and treatment of odors. The cause of objectionable tastes and odors in Southwestern water supplies is believed to be *Streptomyces*, rather than algae.

Surber and Everhart (578) used three applications of nigrosine to control a young growth of *Chara* in a pond. No bloom developed in this pond, whose water remained black for some time. No deleterious effects to bass and sunfish were observed at the concentrations of nigrosine required for weed control. The dye reduced the numbers of zooplankton, but the bottom animals increased in number.

Mackenthun (390) reviews aquatic weed control in Wisconsin. In 1949, 33 lakes were treated with sodium arsenite. From 5 to 10 p.p.m. sodium arsenite controls weeds in various situations without harm to fish life. Hart (278) states that biological surveys not only indicate present conditions in the stream, but also the past pollutional history. A research project established to determine the effectiveness of bacteria as a pollution index found that bacteria were not a suitable index, as representative forms were found in both polluted and unpolluted streams.

Higgins (296) states that the disposal of radioactive wastes into streams exposes many aquatic organisms to a long-continued low-level exposure of radiation. To study the effects of these wastes a tributary of the Clinch River (Tenn.) drainage, which has been receiving radioactive wastes and which contains an apparently normal biota, was selected for extended biological studies.

Bidwell and Kelly (113) report *Salmonella* originating from duck farms near the eastern end of Long Island were polluting oyster beds. These pathogens were found in the oysters; the areas polluted by these duck farms are, therefore, unsatisfactory for shellfish culture.

Chemistry

The FSIWA Research Committee, Subcommittee on Toxicity, Section I, presented a comprehensive review of the effects of many industrial wastes and components thereof on anaerobic and aerobic processes, natural purification rates, stream microflora and microfauna, and on the B.O.D. test (523).

Velz (622) discussed some of the factors which must be considered in securing samples to be used as a basis for calculation of the conditions of receiving waters under varied conditions. In discussing Velz's paper, Clark (169) enumerated some of the TVA sampling techniques, such as following a given mass of water downstream, and emphasized the necessity for the consideration of all phases of the problem in setting up sampling programs. Hyde (322) described the construction of a depth sampler from a commercial pressure cooker.

Lawrance (365) reported on the application of sodium nitrate for control of nuisance conditions in the Androscoggin River. Winkler and Wipf (651) stated that sodium nitrate was more satisfactory than sodium chloride in chemically tracing the flow of water.

There were a number of papers on the borderline where the interests of water plant operators meet those of people concerned with stream pollution. Cross *et al.* (184) discussed the effects of pollution by synthetic detergents upon the production of a satisfactory drinking water. Rohlich and Sarles (518) considered the chemistry of organic compounds responsible for tastes and odors. Muehlberger (432) reviewed the hazards resulting from chemical contamination as related to water supply.

Contamination by particular chemical compounds was considered in two papers. Ettinger and Ruchhoft (221) studied the persistence of mono-chloro-

phenol in polluted river water and sewage dilutions. Lyne and McLachlon (387), investigating the persistence of ground-water contamination by trichloroethylene, noted the toxicity of this chemical and presented a method for its determination.

Tyler (604) and Gould (264) considered factors in the disposal of sewage into tidal flows. The pattern of dilution, retention, and stratification is important and Tyler goes into detail regarding techniques used in studying this factor. Horton (313) reported an intensive survey of the Wabash River, designed to measure the self-purification capacity of that stream. Petru (469) discussed the overloading of sections of the Elbe and Vetava Rivers by industrial effluents.

Matsubara (396) described laboratory experiments designed to evaluate the relationship of such physico-chemical parameters as depth, temperature, and flow velocity with self-purification. Kalabina *et al.* (336) studied the effect of toxic substances in effluents from non-ferrous metal industries on microorganisms and biochemical processes associated with self-purification of water in storage basins. Porter and Bishop (482) described the use of oxidation ponds for the purification of paper mill wastes (ground wood and bleached or unbleached kraft wastes). The ponds afford 13-day storage. The initial B.O.D. of 200 to 230 p.p.m. is reduced to 35 to 90 p.p.m. The greatest purification is obtained during the summer months, corresponding to minimum flows in the receiving stream.

Oxygen Sag and Self-Purification

The calculations involved in fitting B.O.D. data to the unimolecular equation have been the subject of several papers. Thomas (595) presented a simple method of making a graphical approximation of the variables in the basic oxygen sag equation. Later, Moore *et al.* (421) presented a method which gives somewhat better accuracy than the method discussed above, and yet requires only relatively simple calculations. The calculation technique may be modified to compute the lag. In discussing this paper, Ruchhoft (522) pointed out the desirability and limitations of the unimolecular equation, and listed some current studies which may lead to an improved knowledge of biological oxidation.

LeBosquet and Tsivoglou (369) presented a method for making practical calculations in terms of stream loading in connection with oxygen sags. The method uses the dissolved oxygen profile of the stream in connection with the Streeter-Phelps equations as a basis for the calculations, but avoids assumption of oxidation or reaeration constants.

Velz (623) called attention to the utilization of natural purification capacity of streams for sound and economical solution of the municipal and industrial waste disposal problem. Municipal treatment works must be designed to protect against a drought severity expected, on the average, once in 5 to 10 years. In industrial waste disposal, however, it is possible to control production, taking full advantage of the daily trend in natural purification capacity.

A simple graphical scheme is described by Imhoff (323) for the representation of the load on polluted streams.

Stream Standards

The trend toward stream zoning and the setting of water quality criteria based on particular water uses has been further exemplified. In discussing stream quality objectives, LeBosquet (370) stresses that the degree of pollution abatement depends on stream uses, with due regard to the rights of public and riparian owners. Public Law 845 gives to the states the primary responsibility for setting objectives. The word "objective," denoting a desirable ultimate, is preferred over the word "standard," which implies something

fixed and to be reached soon. In setting objectives, it is necessary to provide for normal low stream flows, the proper mixing of effluents, and proper sampling where settling solids or floating substances are objectionable. Examples of stream objectives are given, including those of the International Joint Commission, the Ohio River Sanitation Commission, the New York "Water Classification Standard System," and the Indiana Stream Control Board.

In England, the Rivers Pollution Subcommittee (23) has stated that stream standards are desirable and practicable. No standards have been fixed, however, pending agreement on specific tests to be adopted for measurement of general stream properties.

The New York State Water Pollution Control Board (59) has devised a stream classification system based on the best usage for which a watercourse is utilized, and the water treatment methods needed to satisfactorily provide such usage. Water quality standards are specified for the various classifications of surface waters, tidal salt waters, and underground waters. To illustrate this system, surface waters are classified into some seven categories based on water usage—for example, Class AA used for drinking, culinary, or food processing purposes; Class F used for sewage and industrial waste disposal only. Specific quality standards have then been set for each of these categories.

Pollution control legislation in California has been described by Grayson (270). Through legislation enacted in 1949, a State Pollution Control Board and 9 regional boards were formed and assigned specific powers and duties. The state board (60) has stated its policy on water quality criteria based on various water uses. Bacterial, chemical, and physical characteristics have been assigned specific limitations for each use cited.

The Interstate Commission on the Potomac River Basin (69) has established water quality standards for four stream classifications. Quality requirements are specified in terms of coliform content, color, turbidity, pH, dissolved oxygen, and other characteristics.

Rodger (514) discussed the radiation level considered safe for potable waters and also the monitoring system necessary for a water supply. Muehlberger (432) discussed the establishment of safe limits for toxic substances. Cadmium and hexavalent chromium toxicity limits were reviewed in detail. The Public Health Service standard of 0.05 p.p.m. hexavalent chromium seems amply safe, whereas the exact toxic limit of cadmium is not sufficiently defined by present limited data.

Stream Surveys and Studies

Many comprehensive stream pollution survey programs have been reported. Interim reports are available for certain of the programs and final reports have been made available for others. Mostly, such reports have been printed as separate publications and have been abstracted in the various periodicals. Certain of this literature, as well as other publications, is of a general nature applicable to other survey work.

Mobile laboratory facilities are being more widely utilized for survey work. McDill (401) describes their use on a survey of the Miami River in Ohio. Laboratory analysis made and results of the survey are also reviewed. Sanderson (536) describes mobile operations for routine field examinations in New York State. Some of the problems of stream surveys are also outlined.

The Ohio River Valley Water Sanitation Commission has reported on its second year of activities in a proposed eight-year program (66). General accomplishments regarding stream and wastes analysis and abatement objectives are described. Special projects undertaken by the Commission and

specific municipal and industrial developments regarding pollution abatement are discussed in detail. The Commission also reported an extensive survey recently conducted on the Ohio River (73). This survey involved a two-week, 24-hr. per day sampling schedule from 32 sampling points over a 900-mi. length of the river. Water quality was determined at principal tributaries and major sources of pollution. To standardize laboratory techniques, state personnel were given special instruction at a seminar conducted by the Environmental Health Center, Cincinnati, Ohio.

A comprehensive pollution report on the Clarion River (Pa.) has been prepared by Camp, Dresser, and McKee (159). Significant industrial wastes discussed include wastes from wood distillation plants, pulp and paper mills, carbon plants, tanneries, and a brewery. The pulp and paper mills were found to be responsible for about 93 per cent of the total organic material discharged into the river. Criteria for establishing quality standards commensurate with water uses and the assimilation capacity of streams for carrying wastes are discussed. Abatement procedures are recommended, together with cost estimates.

The Massachusetts Department of Public Health (61) has reported on its investigation of nuisance conditions on the shores and beaches at five cities along a 45-mi. coastline in Massachusetts. Bacterial loadings, travel of sleek areas, and existing sewer outfalls were studied. Enforcement of rules governing pollution of inland and tidal waters, together with further investigations, were recommended.

Pollution conditions along the Sudbury River in Massachusetts, were reported by the Sudbury Valley Commission (62). Certain pollution controls such as zoning of land uses and diversion of sewage flow, were recommended in view of the many uses of the river.

A water quality survey of the Hampton Roads, Va., shellfish growing area has been reported (88). Comparison with a 1934 survey indicates that the general water quality is better at the present time. A potential hazard in the area is the discharge of raw sewage from ships.

A condensation has been published (58) of the "Interim Report to the International Joint Commission" regarding pollution in the St. Clair River, Lake St. Clair, Detroit River, and St. Marys River. The boundary-water investigation involved a survey of water quality conditions and sources of pollution, the establishment of objectives for water quality in the area, and cost estimates for both industrial and municipal waste treatment to meet those objectives.

Love (383) has reviewed the general chemical quality of both surface and ground waters in the Middle Atlantic States. Areas subject to pollution are briefly discussed with regard to type of pollution and possible remedial measures.

Bacterial survey of streams and bathing beaches at Cleveland was reported by Delos (197). The pollution of the beach waters in 1949 was in excess of that found previously, and several times higher than any known permissible standard. Rainy weather and the operation of storm-water overflows increase the pollution level.

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OHIO VALLEY COMPACT UPHELD BY U. S. SUPREME COURT

In a unanimous decision handed down on April 9, 1951, the U. S. Supreme Court ruled that West Virginia continues as a member of the eight-state Ohio River Valley Water Sanitation Compact. This reverses the action of the Supreme Court of Appeals of West Virginia, which had declared the state's participation in the Compact to be unconstitutional [see THIS JOURNAL, **22**, 11, 1474 (Nov., 1950)]. The sweeping decision also settles any doubts about other states' participation; three had ratified the Compact on condition that West Virginia also be a participant.

The majority opinion, delivered by Justice Frankfurter, disagrees with that of the state Court and says there was no violation of the state Constitution, as the Compact ratification constitutes a "conventional grant of legislative power," and that the agreement to appropriate is no debt. These two points had been the major issues on which the state Court had based its decision.

Although all the Justices agreed on the validity of West Virginia's participation in the Compact, two based agreement on other grounds and went to the unusual procedure of writing concurring opinions. One held that the Supreme Court had no right to interpret the state Constitution, but that the Compact was supreme to state law, so was valid. Another based his concurrence on the principle that a state could not make a contract and then discover some loophole to escape it.

In commenting on the Supreme Court decision, the *Cincinnati Enquirer* noted that it has more far-reaching implications than would seem apparent at first glance, as it not only establishes the basic validity of interstate water sanitation compacts, but also helps to clarify the legal status of several other interstate compacts covering other activities.

Sewage Works

SEWAGE DISPOSAL AT TAMPA, FLORIDA *

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Partner, Greeley and Hansen, Consulting Engineers, Chicago, Ill.

The city of Tampa and the surrounding metropolitan area has been faced for many years with the problem of providing sewage disposal facilities to abate dangerous and obnoxious pollution in the Hillsborough River and in the marginal bay waters. The removal of this pollution is now in progress by the construction of many miles of sewers, a system of intercepting sewers, and a sewage treatment plant. There is little of the dramatic in this project but more of the determination of the city to face the problem squarely and to find a solution. This has involved careful planning from all angles, including legal and financial procedures; public opinion, as reflected in the official actions of the city; and the development of the engineering aspects of the project.

Population Growth

The city of Tampa is located at the upper end of Tampa Bay at the mouth of the Hillsborough River. It is not a city affected materially by the tourist and resort trade, but is a more typical commercial and industrial American community. Its growth over the years has been affected to some extent by the general increase in population of Florida resulting from the resort business, but the growth has been steadier and has a firmer foundation.

The present city limits were established in 1924 at the end of the land boom in Florida. This stability of political boundaries has resulted in the development of a metropolitan or suburban area surrounding the city limits and a large part of the more recent population increase has occurred in these suburban areas. The record of population growth in the city and in the immediate metropolitan area may be summarized as follows:

Year	City of Tampa	Suburban Area	Total
1900	15,839	—	—
1910	37,782	—	—
1920	51,608	6,000	57,608
1930	101,161	25,000	126,161
1940	108,391	35,000	143,391
1947 (Est.)	130,000	45,000	175,000

Existing Sewers

There have been practically no major additions to the sewer system in the city since 1924. Prior to that date sewers were constructed in part by the city and in part by real estate developers, with the result that the present system has not been well integrated into a comprehensive program. The sewered areas within the city comprise a total of about 7,000 acres, or 58 per cent of the land area, in which service is available to about 80 per cent of the population. In the entire metropolitan area surrounding the city, sewers have been built to serve only about 800 acres. All of the sewered area is located on the peninsula between Hillsborough Bay and Old Tampa Bay, closely adjacent to and southwest of the city.

As an indication of the unintegrated development of the sewer system in

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the city, part of the sewage from the western section of the city is pumped across the Hillsborough River and discharges into the estuary east of the downtown district, whereas one section in the eastern part of the city is served by an outlet crossing the downtown area and discharging into Hillsborough River. The records of the existing system are incomplete and this has resulted in a difficult problem to integrate the existing system into a well-planned program for providing a master system for the entire city and for the surrounding suburban areas.

There are about 40 outlets discharg-

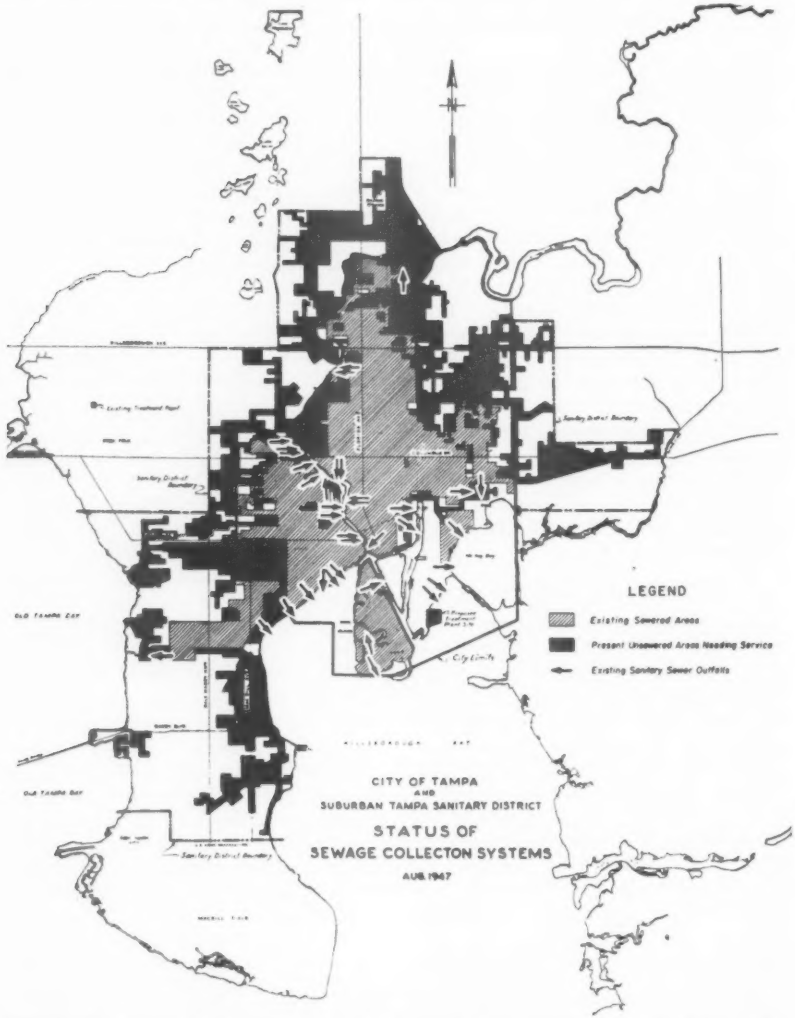

FIGURE 1.—Status of sewage collection systems in metropolitan area of Tampa, Fla., as of August, 1947.

ing the sewage from the city and the small sewered area in the suburbs into the Hillsborough River and the surrounding bays (Figure 1). Only four of these are provided with any treatment. One of the large outlets discharges through an Imhoff tank into Ybor Estuary. There are two other smaller Imhoff tanks and one septic tank. All of these tanks are badly overloaded and accomplish little treatment of the sewage. The other outlets discharge directly into the Hillsborough River and into the shallow shore waters of Hillsborough Bay.

Previous Studies

That the city has recognized the problem of sewage disposal is evidenced by the various studies undertaken from time to time of conditions in the marginal waters and Hillsborough River. In 1927, Nicholas Hill, Jr., reported on the condition of the waterways adjacent to Tampa and recommended installation of collecting sewers and treatment of the sewage by fine screens at several locations with the effluents discharged to the bay and the river. Later reports recommended construction of intercepting sewers and treatment facilities, comprising sedimentation and secondary treatment, with discharge of the effluent into the river or shore waters. In 1938, the Florida State Board of Health surveyed the river and bay and found a marked depletion of oxygen (less than 2.4 p.p.m. D.O.) near the mouth of the Hillsborough River, as compared to more than 7 p.p.m. above the city sewer outlets. This study revealed a coli-aerogenes index (per 100 ml.) in excess of 250,000 near the outlet of the river. It is apparent that this condition has been aggravated by the increase in population and industrial development in the last decade.

Other studies of the shore waters of Hillsborough Bay have revealed definite evidence of sewage pollution, which has been contributory to obnoxious odors and discoloration of house paint along Bayshore Boulevard.

During World War II this unsanitary condition was aggravated by the considerable increase in population and an attempt was made to organize a metropolitan district to accomplish a clean-up program for the entire area. Although this program did not materialize, it eventually resulted in the formation, in 1945, of the Suburban Tampa Sanitary District, which embraces the developed areas surrounding the city with a land area in excess of 22,000 acres and with a resident population estimated in 1947 to be 45,000 or more.

Recommended Project

A comprehensive study of the needs of the entire metropolitan area, undertaken jointly by the city and the Sanitary District in 1947, resulted in the recommendation of a project for sewage disposal to serve the entire area and outlined a program for providing service to all developed areas. This program was designed to eliminate the present polluted condition of the waterways and also to eliminate the use of septic tanks. In areas not served by the existing sewer system, which includes almost all of the Sanitary District and considerable areas in the city, septic tanks are the only available method of sewage disposal. In many areas, where the ground-water level is high or where the terrain is flat and subject to flooding during the heavy summer rains, this method of disposal is ineffective and often results in the overflow of untreated sewage and dangerous contamination on the ground surface.

The recommended project for the metropolitan area (see Figure 2), to provide sewer service to all developed areas and to provide sewage disposal for the entire area, was estimated to cost about $25,000,000. The biggest part of this cost, or about $13,000,000, was for the construction of street or service sewers, largely in the Sanitary

District. The sewage disposal system, part in the city and part in the District, was estimated to cost about $12,000,000. It was apparent that the entire project could not be properly accomplished at one time and that a progressive program of construction would be necessary. It was decided by the city to undertake its part of the program and by the District to proceed with a part of its system to serve the most heavily populated area on the peninsula between Hillsborough Bay and Old Tampa Bay. The estimated cost of the part of the project within the city was $11,800,000, of which $9,000,000 was construction cost, with $7,100,000 for sewage disposal and $1,900,000 for street or service sewers. The Sanitary District project for the selected area was estimated to cost $3,800,000 with a construction cost of $2,865,000, of which $700,000 was for the intercepting sewers and other parts of the sewage disposal system in the District and $2,165,000 was for street or service sewers.

The city and the District, acting independently, each approved the recommendations resulting from the study of a comprehensive system for the metropolitan area and started proceed-

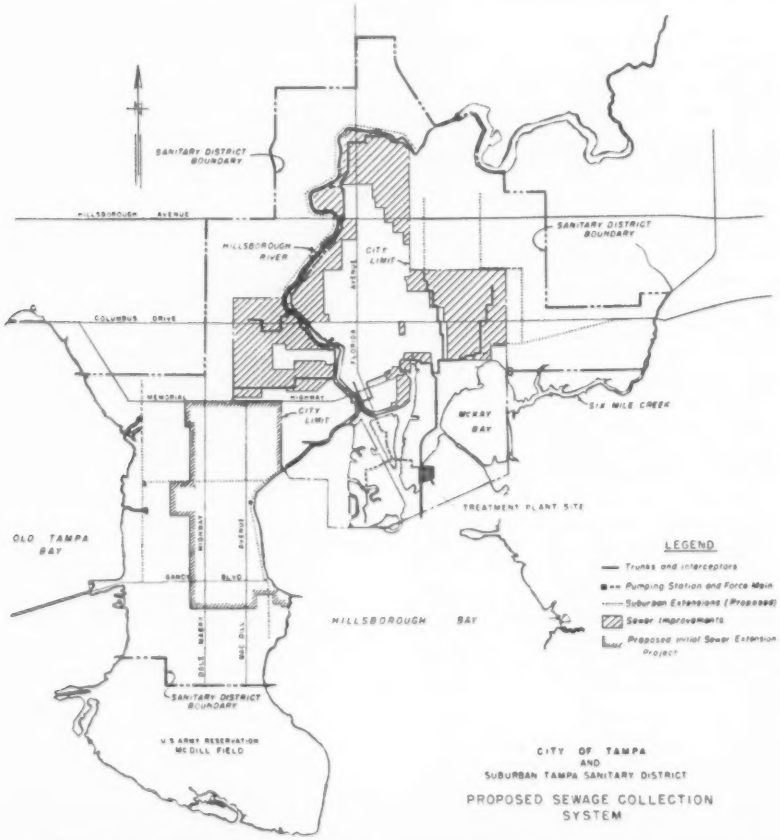

FIGURE 2.—Proposed sewage collection system for Tampa metropolitan area.

ings toward actual accomplishment of the improvements. That part of the master sewage disposal system within the city limits was to be built by the city, together with the necessary sewers to provide direct service. The Sanitary District was to construct the parts of the system outside the city limits necessary to provide the direct service and also outlets to the sewage disposal system constructed by the city. Both the city and the District employed the same financial, legal, and engineering organizations.

Progress on Program

The city part of the project has proceeded with only minor delays and by October, 1950, all essential parts had been placed under construction. Financing of the Sanitary District part of the project has been much more difficult, principally because of the much greater cost resulting from the need for constructing a complete system, including both service sewers and a system of intercepting sewers. This resulted in a considerably higher cost per unit of property, as well as a higher service charge. It was recommended that part of the cost of the District system be paid by assessments. This procedure requires an election at which not less than 50 per cent of the freeholders participate and a favorable vote of not less than 50 per cent of the votes cast. The cost of the improvements in the selected area of the District resulted in use and assessment charges which raised considerable objection among property owners. As a result, the Sanitary District part of the project has been delayed pending development of some other financing procedure, which may require legislative action.

The system now under construction in the city includes about 68 mi. of street or service sewers serving marginal areas in which considerable development has taken place since the last major sewer construction in 1924. These sewers are designed for extension into other areas not as yet developed.

Within the city a system of intercepting sewers, pumping stations, and force mains collect the sewage from all existing outlets and from all of the new service sewers under construction. This system includes about 28 mi. of gravity sewers ranging in size from 12 to 60 in. in diameter, force mains 12 to 54 in. in diameter, 12 pumping stations, 6 sub-aqueous crossings of the Hillsborough River and navigable channels, and pertinent special and standard structures. The collecting system has been designed with capacity to receive the sewage flow from the entire area of the city and from the adjacent Sanitary District when and if collecting sewer systems are constructed in the suburban areas. Thus, a convenient outlet to the city system has been provided for the Suburban Tampa Sanitary District areas. The benefits of the long-range planning in this program by the city will be recognized when sewer systems are installed in these areas.

Type of Treatment

The entire flow of sewage produced in the city, and eventually in the Sanitary District, is conveyed to the treatment plant located on Hooker's Point, which extends into Hillsborough Bay (Figure 2). The treatment plant comprises sedimentation and chlorination of the sewage, with sludge disposal in covered tanks and drying on open beds. With the discharge of the treated effluent into the deeper waters of Hillsborough Bay adjacent to the main ship channel, it has been estimated that treatment by sedimentation will be adequate for many years. The removal of the settleable solids will reduce or eliminate the formation of sludge deposits and will eliminate unsightly conditions along the shore. Conditions in the Bay are favorable to dispersion and should result in no damaging depletion of the oxygen content.

Chlorination of the effluent will remove the hazards of bacterial pollution.

Design of Sewers

The design of the sewers, including both the systems for direct service and for the collection of the sewage, was based on conditions that can be anticipated in the year 2000. This includes a population forecast for the city at that time of 208,000 and for the Sanitary District of 127,000, or a total of 335,000. It is anticipated that service will be provided for all developed areas by that date.

For the treatment plant and other facilities which can be readily enlarged or duplicated, it was considered proper to base the design on conditions that could be anticipated in 1970. It was also considered probable that a progressive program for the construction of service sewers in the Sanitary District would not be completed prior to the year 2000. Based on this kind of a program, it is expected that the population connected to the system will be about 235,000 in 1970, and this population has been used as a basis of design for the treatment works.

Data obtained from gagings of existing sewer outlets, a study of the records of water use, and of existing sewage pumping station operation, as well as a survey of industrial water use, were used as the basis for estimating the unit quantities of sewage that can be anticipated in the future. These quantities have been assumed as follows:

Domestic sewage (g.p.c.d.):	
Small houses or congested districts	50
Medium districts	65
Large residences or open districts	80
Commercial and business districts (g.p.a.d.):	
Center of town areas	10,000
Outlying areas	5,000
Industrial districts (g.p.a.d.):	
General allowance	2,500
Present industries as indicated by industrial survey	
Ground-water infiltration max. rate (g.p.a.d.):	
Present sewered areas	500 to 2,500
Newly sewered areas	250 to 500

Application of these estimated quantities to the estimated population and areas, based on the anticipated land use, results in the probable quantities of sewage that will be produced in each area in the year 2000. Based on these assumptions, it has been estimated that the average sewage quantity in 1970, from a connected population of 235,000 would be 36.0 m.g.d. or 153 g.p.c.d., and that by the year 2000, when the entire area of the city and the Sanitary District (population estimated at 335,000) would be connected, the average sewage quantity would be about 52.5 m.g.d., or 157 g.p.c.d.

As development of individual areas within the limits of the project will not follow the patterns estimated, a design factor has been applied to the annual average sewage quantity in relation to its proportion of the total estimated sewage quantity. The factor varies from a ratio of 2.4 when applied to an annual average quantity of 30 or more m.g.d. to 4.8 when applied to a sewage quantity of 1.0 m.g.d. This results in a somewhat greater unit capacity in the smaller sewers at the upper ends of the system, where the effect of disproportional development and sharper maximum rates of flow are greater.

Industrial Wastes

The principal waste producing industries in the Tampa area include two breweries and five citrus processing plants, all of which contribute materially to the strength of the sewage as measured by suspended solids and 5-day B.O.D. It was estimated that these industrial wastes would add about 15 per cent to the suspended solids load and about 25 per cent to the 5-day B.O.D. load, but that the resulting mixed waste would be amenable to treatment by sedimentation and disinfection with chlorination. The design of the treatment facilities has been predicated on an average sewage with 205 p.p.m. of suspended solids and a 5-day B.O.D. of 215 p.p.m. These

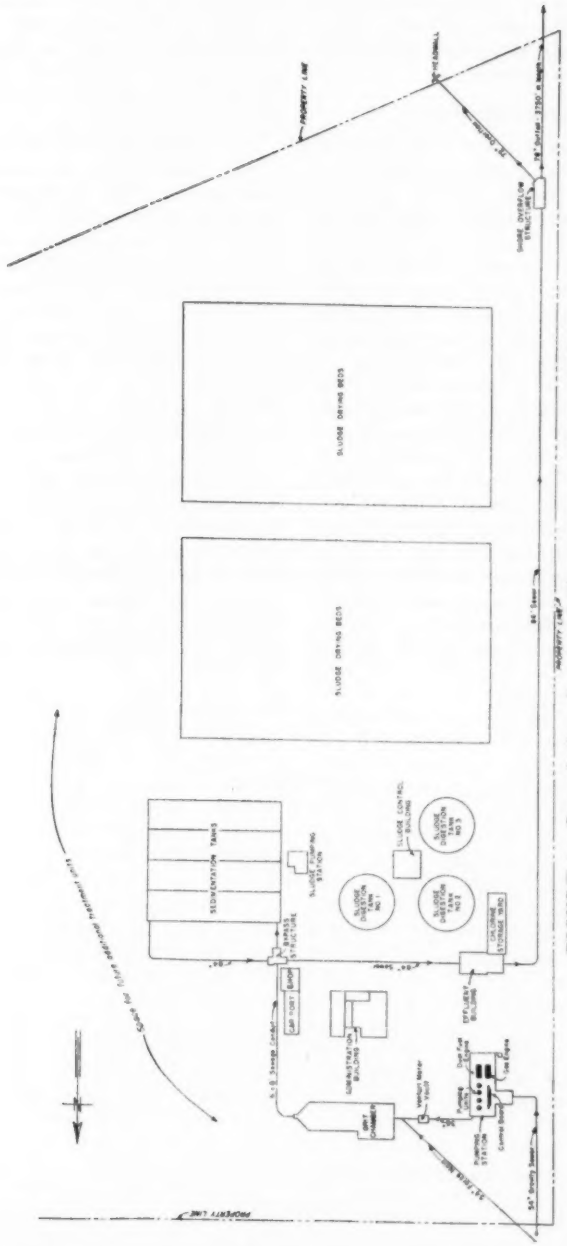

FIGURE 3.—General plan of proposed Tampa sewage treatment plant.

characteristics are recognized as being variable, as the citrus industry operation is seasonal, being most active during the winter months.

Treatment Plant

The treatment plant (Figure 3) is of conventional design comprising mechanically cleaned screens and grit chambers, rectangular sedimentation tanks with a displacement period of 1.75 hr. on an average sewage flow of 36.0 m.g.d., and chlorination facilities with a retention time in the outfall in excess of 15 min. under any anticipated condition of flow. Solids removed from the sedimentation tanks are to be digested in three sludge tanks equipped with floating covers and having a total volume of 338,000 cu. ft. (1.45 cu. ft. per capita for the design population of 235,000). Sludge is to be dried on open beds and it is anticipated that dried sludge will be of use as a soil conditioner in nearby citrus groves. One gas engine and one dual-fuel engine will provide all power required for operation of the sewage treatment plant, but a stand-by connection to the local power company lines is also provided in case a maximum demand occurs with one of the engine generators out of service.

Effluent Discharge

The effluent from the sewage treatment plant is to be discharged into the waters of Hillsborough Bay adjacent to the main ship channel at a point about 3,500 ft. south of the treatment plant site and the end of Hooker's Point (Figure 4). This location for discharge of the effluent was determined after a considerable study of current conditions in the bay and the effects of wind and tide. Float studies were made over a period of a month or more in an endeavor to determine any predominant currents or tide effects that would have a bearing on the location of the point of discharge. Due to the shallow waters over most of the bay area, it was not found possible to arrive at any definite conclusion as to the advantages of one location over another. There appeared to be no pre-

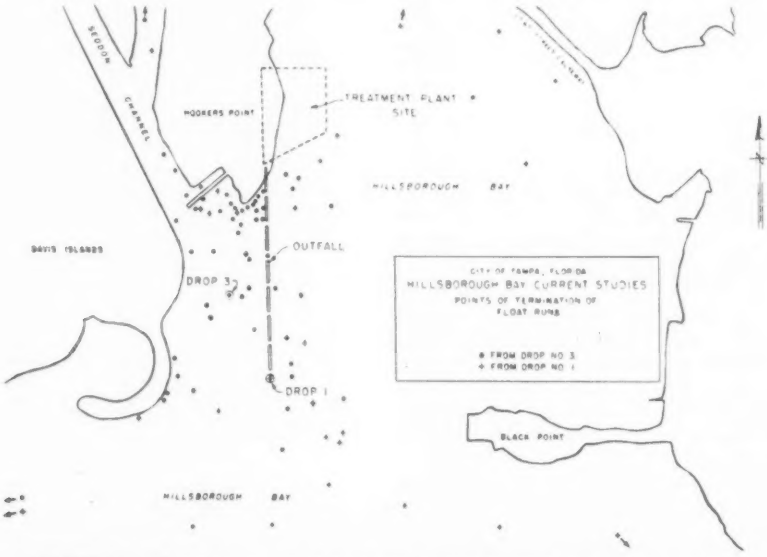

FIGURE 4.—Terminal points of float runs in Hillsborough Bay current studies.

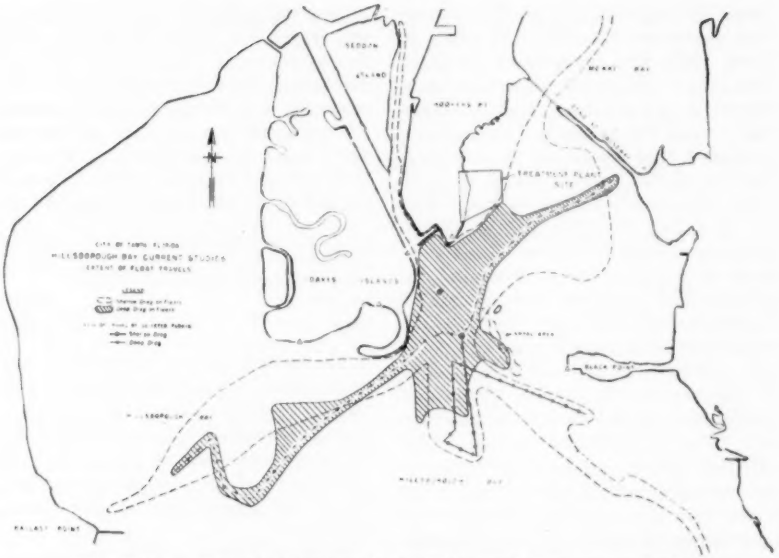

FIGURE 5.—Extent of float travels in Hillsborough Bay current studies.

dominant currents, and in general the effect of the tide was subordinated to wind-induced currents. In almost all cases the drift of floats was with the wind and in many cases against the tide (see Figures 4 and 5). The shallow depth of water in the bay prevented the use of very deep floats, as they became stranded before any predominant drift could be noted. Under these conditions it was considered most desirable to provide as long an outlet as practical and a discharge as far as feasible from the shore in order to accomplish the greatest dispersion and oxygen recovery. The point of discharge selected is in 30 ft. of water adjacent to the main ship channel at a point off the southerly end of Davis Island, where the float studies indicated the best probability of an east-west current, as well as the best effect of tide action.

Costs and Bond Issues

The preliminary report on the comprehensive project for sewage disposal for the Tampa metropolitan area included cost estimates of the parts of the project within the city totaling $11,600,000. These estimates were made late in 1947. The financing procedure undertaken by the city, as developed by the engineers, the legal, and the financial advisers, was based on revised estimates prepared in September, 1949, in the amount of $13,000,000. Issuance of this amount of sewer revenue bonds was provided for in a resolution passed by the city in July, 1949. In September, 1949, proposals were received for an initial group of construction contracts comprising parts of the intercepting sewer system, the street sewers or sewer improvements, the river and channel crossings, and some of the structures of the sewage treatment plant. At about the same time bids were received for the sale of an initial installment of $8,000,000 sewer revenue bonds. In all of the preliminary studies of the financing procedure, an interest rate of 3.5 per cent was contemplated but the actual bids on the bonds resulted in an interest rate of about 3.24 per cent. Additional pro-

posals for another group of construction contracts were received early in June, 1950, and for a third group in July, 1950. These three groups of construction proposals included essentially all of the authorized project and indicated that financing in the total amount of $12,000,000 would be sufficient to complete the project, a reduction of $1,000,000 from the $13,000,000 authorized issue of bonds. Bids were received for the sale of a second installment of bonds, in the amount of $4,000,000, late in July, 1950, which resulted in an interest rate of about 2.65 per cent. Thus, the average rate of interest on the entire amount of bonds sold to date is about 3.02 per cent. The $1,000,000 reduction in the principal amount of bonds issued and the favorable interest rate at which the bonds have been sold has resulted in a total saving in financing costs of about $3,000,000.

As of October 1, 1950, construction is in progress under 32 contracts, including all major parts of the sewerage and sewage disposal systems in the city. A comparison between the several estimates and the actual contracts is as follows:

	Construction Costs		
	Preliminary Report Est.	Estimate of Sept., 1949	Contract Amounts
Street sewers	$1,900,000	$2,438,000	$2,063,669
Intercepting sewers	3,683,600	3,942,600	3,449,833
Force mains	531,200	561,000	613,472
Pumping stations	635,200	1,045,400	816,059
Treatment plant	2,000,000	1,950,000	1,627,289
Outfall	250,000	363,000	384,650
Total	$9,000,000	$10,300,000	$8,954,972

Service Charges

The financing of the entire program to provide sewer service and sewage disposal for the city has been undertaken under special legislation authorizing the city to issue bonds secured only by revenues from service charges applied against users of the system. This procedure required establishment of sewer service rates sufficient to pay all costs of operation and maintenance; pay interest on the bonds issued; retire the bonds; and provide for renewals, replacements, and extensions to the sewerage and sewage disposal systems. In respect to the proposed $13,000,000 bond issue, it was estimated that the total revenue required from such service charges in 1960 would be as follows:

Operation and maintenance costs	$306,600
Debt Service (3.5% Interest)	657,625
Renewals, replacements and extensions	146,675
Total	$1,110,900

The actual cost of the project and the reduced interest rate allows an allocation of a larger part of the total revenue to renewals, replacements, and extensions (estimated at about $248,000 in 1960, or about $100,000 more than the amount included in the preliminary estimates).

To provide this revenue, an analysis was made of the water use records in the city and of income from such water use. As all of the water services in the city are metered, it was considered equitable to base the sewer service charge on the amount of water used. A study of the water bill records showed that a three-part rate would provide the required revenue. Consequently, a base rate was established in the bond authorizing resolution comprising the following:

1. A sewage disposal service charge of 100 per cent of the monthly water bill, with a 10 per cent discount allowed for prompt payment.

2. A sewer improvement service charge of 35 per cent of the monthly water bill, with a 10 per cent discount allowed for prompt payment, or a minimum of $1.00 per month. This charge is to amortize a part of the cost of the new sewer improvements (street or service sewers) and is to be made against properties connecting to these new sewers until a total of 240 monthly payments have been made.

3. A connection charge of $15 against all connections made to the

sewer system after the sewage disposal system is in operation.

The resolution also permits establishment of regulations relating to charges for service, including adjustments or credits for water used and not reaching the sewer system and for special charges or credits for industrial wastes imposing a greater or less burden on the sewage disposal system than the average sewage entering the sewer system.

This schedule of service charges was discussed at a public hearing in December, 1948, attended by a hundred or more interested citizens. There was comparatively little expressed opposition to the schedule. The principal question had to do with the method of allowing a credit for water used but not reaching the sewer system. A detailed study is now in progress to determine a schedule of surcharges for strong industrial wastes and an acceptable procedure for allowing credits for large volumes of dilute industrial wastes and for water used by the individual householder, principally for lawn sprinkling, and not reaching the sewer system.

Status of Construction

Active construction has been in progress since January, 1950, on sections of the intercepting sewers, the sewer improvements, the river and channel crossings, and some structures of the treatment plant. All of the essential parts of the project are now under contract, with bids yet to be received only for the administration building and the roads and walks at the treatment plant. As of October 1, 1950, construction work in the amount of about $2,000,000 had been completed. The remaining work is scheduled to be completed so that the entire system can be placed in operation before the end of 1951.

Acknowledgments

It has been possible for this very necessary public health project to progress to its present status only through the cooperative efforts of the city and its several advisers. The assistance rendered by Robie L. Mitchell in working out the legal problems and of W. R. McGill and George Ragsdale, of Lehman Bros., in financial matters, contributed to the favorable acceptance of the financing program by investors. The enthusiasm and hard work of such city officials as Mayor Curtis Hixon, City Attorney Karl E. Whitaker; City Controller H. D. Pelhank, Superintendent of Public Works Roy K. Van Camp, and his assistant, B. M. Duncan, and the cooperation of the Board of Representatives has been inspirational.

Design of the sewer improvements and the intercepting sewer system and management of the necessary field surveys was carried out for Greeley and Hansen by Donald Newton, now resident engineer in charge of construction. John T. Walbridge is construction engineer for Greeley and Hansen in charge of supervision and inspection of the work in progress.

DISCUSSION

By David B. Lee

Director, Bureau of Sanitary Engineering, State Board of Health, Jacksonville, Fla.

As Mr. Langdon has stated, there is little or no drama or glamour attached to the Tampa project insofar as sanitary engineering is concerned, as the program is one of a conventional nature. However, the program now under construction will provide adequate sewerage and treatment facilities so that all domestic and industrial waste within the city limits may be collected and given primary treatment. This program, the largest now under con-

struction in the State of Florida, has a feature that every progressive city should incorporate; that is, the establishment of a master plan, not only for the entire city but also for the suburban areas. This is discussed later herein.

The city officials and the many citizens active in bringing this program to fruition are due high commendation for their long-range vision and progressive approach to solving this problem.

There is no reason to discuss the condition of the Hillsborough River or marginal waters around Tampa. The State Health Department's last survey was made in 1938 and there has been progressive degradation of the waters since that time. The odors and discoloration of the homes near these waters speak for themselves.

Tampa, like most cities, in the past several decades has installed its sewers in hit-or-miss fashion, constructing sewers for any small subdivision being developed at that moment. Real estate developers and industries, all with their individual sewer networks and outlets into the nearest body of water, constructed with no comprehensive program at all. It it probably safe to say that this type of program and construction is still going on, although all State Health Departments are strongly advocating the establishment of comprehensive plans so that any new sewers can be incorporated into the over-all picture.

Mr. Langdon pointed out some of the unintegrated sewer developments of this particular system. It should be pointed out that several of these outlets did have Imhoff tanks and/or septic tanks. Although these did remove some of the heavier solids, this type of works has never been considered as affording much treatment in the State of Florida.

With the completion of the Tampa program, the major problem remaining will lie in the fringe areas just outside of the city. In 1945 there was formed a large, firmly fixed Sanitary District covering an area in excess of 22,000 acres with a resident population of about 50,000. The Suburban Sanitary District and the city proceeded logically and wisely toward an integrated system so that this fringe area might be covered with a sewer system and the flow handled through interceptors and treatment works of the city. The financial problem in the fringe area appeared to be greater than the individuals could handle. There are several already-established small sanitary districts within the large district that have obsolete and inoperative treatment works and poorly constructed and disintegrating sewers, which are now contributing pollution to the waters in this area.

The septic tank problem is more than just a term in this area. With the rise of the water table during the rainy season to a point higher than ground elevation, and the water table not far below the ground surface during so-called normal times, plus a very tightly consolidated hardpan or impervious material, septic tanks are a very bad risk insofar as public health is concerned. We are at present having a difficult time attempting a solution in the real estate developments and subdivisions, as well as at single-unit homes now under construction in the Inter-Bay Peninsula area. Whereas the State Health Department has long advocated a master plan covering both the city and the Suburban Sanitary District, as Mr. Langdon outlines, we feel that in many of these areas sanitary district legislation of a permissive and enabling nature would aid this program; in other words, permissible legislation allowing small areas to form their own districts, negotiate with the city for ultimate disposal, and thus provide for a step-by-step program, rather than a definitely defined area with a definite coverage of the sewer network. Admittedly, this is not the desired goal, but it would provide a workable tool which could be used at

this time. We are now recommending that all subdivisions and developments in the Inter-Bay area install their own sewer networks and provide adequate treatment facilities so that they may be incorporated in the future master plan. This is a long-range program, and most necessary at this time, but with Tampa taking the lead it is expected that additional pollution abatement will be accomplished in this area in this way.

Primary treatment was approved in the design of the treatment works in the Tampa area with the understanding that the treatment plant be located so that additional units might be provided in the event they are needed—either a duplication of the present plant or for secondary treatment when indicated. Sludge drying beds were designed for 0.75 sq. ft. per capita. This is felt to be a safe criterion, expected to give many years' service. Experience gained through the University of Florida sewage treatment plant indicates a possibility of reducing our criteria for sludge drying bed area to about 0.50 to 0.66 sq. ft. per capita. We are also expecting to lower our criteria for digester capacity based on Florida experience, but are not quite ready to announce these data.

Another excellent design incorporated in this plan is that for the sewers. Both the system for direct service, and the one for collection of the sewage have been based on an anticipated condition in the year 2000. Too many sewer systems—some constructed in the not too distant past—cannot be expanded because of the overloaded condition of certain elements. Although Florida has had a rapid population growth in recent years, we still think that with good engineering planning, sewers can be designed to take care of anticipated population within fairly close limits. It is felt to be both wise and economical to design a plant to meet conditions in 1970, thus being able to accommodate normal expansion during the next 20 years.

It is hoped that the five citrus plants and two breweries will not present any problem in the operation of the treatment plant. Extension of the outfall to the distance indicated is deemed wise, due to the fact that considerable tide action and a shallow area would not have given as much continuous dilution. But with a 30-ft. depth of water adjacent to the main ship channel, it is expected that a chlorinated effluent will not produce much of a public health problem.

PRIORITY SYSTEM TO BE EXPANDED

Beginning with the third quarter of the year, effective July 1, 1951, the Controlled Materials Plan will go into effect through the National Production Authority. Under this plan, defense and defense supporting production and construction will be programed and essential materials made available, using the same common denominators as in World War II—steel, copper, and aluminum. At the same time, NPA will encourage other production to continue to the extent that materials are available and other regulations permit.

Developed during World War II, the Controlled Materials Plan proved itself to be the best method to guarantee that a balanced flow of materials is made available on time and in sufficient quantity for essential production.

Forms, operating instructions, and other pertinent material are to be made available during May so that producers coming under Controlled Materials Plan programs may become acquainted with them before the plan goes into effect. Copies of the regulations and procedural forms will be available through the Department of Commerce, Washington, D. C., and its field offices, as well as through national trade associations and similar groups.

CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL *

III. FIELD STUDIES ON *ASCARIS* EGGS

By Willem Rudolfs, Lloyd L. Falk, and Robert A. Ragotzkie

Vegetables grown on polluted soils may carry on their surfaces the eggs of worms parasitic to humans. It has been shown in the general survey of the literature (11) that certain of these eggs, especially those of *Ascaris* or *Trichuris*, are markedly resistant to external conditions. The external parts of the life cycle of the *Ascaris* and *Trichuris* parasitic worms are as follows: the eggs are passed in the feces, embryonate outside the body in the soil or fecal material, and are then infective to anyone who consumes them directly. The organisms require no intermediate host. Because the eggs are very resistant to conditions outside the body of the host and are passed in the feces of the host, it is conceivable that they may be found viable on the external parts of plants grown in polluted soil or receiving direct applications of fecal material.

It has been shown (12) that the danger is not great for the transmission of enteric bacterial diseases by tomatoes grown in polluted soil or even receiving direct applications of feces, provided sufficient time elapses between application and harvest. Under such conditions decontamination may be entirely unnecessary for bacterial removal. On the other hand, decontamination with respect to the more resistant helminth eggs may be essential.

Methods of Study

Selection of Organism

Eggs of *Ascaris* were used as a test organism because their great resistance to external conditions makes them most likely to be found viable on vegetables grown in polluted soils. The human worm is *Ascaris lumbricoides*. As no eggs of this organism were readily available, it was decided to use those of the pig ascarid, *A. suum*. Caldwell and Caldwell (3) have pointed out that in spite of the morphological, serological, and physiological near identity of the two worms, the absence of human ascariasis, even in an extremely unsanitary environment in close proximity to pigs with a high rate of infection, would point to a difference between the two with respect to host specificity. Payne, Ackert, and Hartman (9) showed that the human ascarid worm will develop to the lung stage in the pig, but no further. Consumption of mature *A. suum* eggs by two of the authors led to no ill effects nor to passage of eggs in the stools for as long as 14 to 22 months afterward. Here is direct evidence of the dissimilarity of the two worms. Otto (8) showed that the eggs of the two worms behaved similarly in their resistance to desiccation.

It was felt that results of field studies with *A. suum* would closely represent those obtainable with *A. lumbricoides* and *A. suum* could be studied safely in the laboratory. A supply of fresh eggs was always available from mature worms collected on offal screens of a pig slaughterhouse.

Collection of Eggs

The eggs used were obtained from the first 1.5 in. of the uteri of adult female worms (1). The eggs were squeezed from the uteri and suspended

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

in tap water. Tests were made to check egg fertility. Miura and Nischiuchi (7) described fertilized eggs as having spaces between the egg cytoplasm and the egg ends. The unfertilized eggs are longer, have less of an albuminous coating, and the cytoplasm completely fills the egg and is alveolar. Such unfertilized eggs were rarely found to make up more than 1 or 2 per cent of those examined.

Viability of Eggs

To test the viability of *Ascaris* eggs after a given treatment, they were incubated and examined for the development of motile embryos. Brown (2) showed that pig ascarid eggs will completely embryonate in 10 or 11 days at 30° C. and in 23 to 26 days at 21° C. This is in agreement with the results of Ransom and Foster (10). Incubation of the eggs used in these experiments also showed almost complete embryonation in 10 days at 30° C. Consequently, this temperature and time period was selected to determine viability by incubation and microscopic examination for embryonation. The development of the eggs takes place in the following stages (8): undeveloped, 1 cell; early morula, 2 to 16 cells; late morula, 16 cells to complete morula; tadpole, incurved morula to early vermiform; embryonated, early vermiform to complete active vermiform.

Survival of *Ascaris* Eggs on Vegetables in the Field

Eggs of *Ascaris* have been found to be markedly resistant to external conditions when stored in the soil or soil-feces mixtures, a large percentage being able to survive several weeks under proper conditions. The work of Caldwell and Caldwell (4), Brown (2), Otto (8), and Spindler (14) has indicated, however, that desiccation and sunlight are the greatest lethal factors to the development of *Ascaris* eggs. Thus, crops in the open field, which may be subject to drying heat or sunlight, might fairly rapidly rid themselves of dangerous helminth eggs deposited on their surfaces. Experiments were carried out in which the survival of *Ascaris suum* eggs was determined after the eggs had been deposited on the surfaces of tomatoes and lettuce growing under field conditions.

Evaluation of Ascaris *Eggs on Vegetable Surfaces*

Faust *et al.* (5)(6) recovered approximately 80 per cent of the helminth eggs in feces by the use of zinc sulfate flotation methods. Feces were mixed with $ZnSO_4$ solution of specific gravity 1.180 and centrifuged. The eggs floated, while most of the organic material settled to the bottom. It was hoped that *Ascaris* eggs on vegetable surfaces could be determined by this technique on the macerated vegetable. It was found, as in the case of bacteria, that the eggs were unharmed by the action of a Waring blender, which was used to accomplish maceration. However, when eggs were mixed with the macerated tomatoes they could not be separated and concentrated because of the gelatinous matrix of the pulp.

Caldwell and Caldwell (4) and Spindler (13) used antiformin (6 per cent sodium hypochlorite) in freeing helminth eggs from dirt particles in the determination of their concentration in soil samples. The concentration of antiformin used (30 per cent) was noninjurious to the eggs so far as viability was concerned. It was noticed in the present work that the outer gelatinous layer of the eggs was removed by this treatment. Furthermore, eggs adhering to smooth tomato surfaces were completely removed by treatment with 30 per cent antiformin.

The following procedure was adopted for the evaluation of *Ascaris* eggs on vegetable surfaces. The vegetable (whole tomato, or lettuce after being broken into separate leaves) was agitated in 30 per cent antiformin for 5 min. The antiformin was poured off, the vegetable was rinsed with tap or distilled water and the rinsings were

TABLE I.—Survival of *Ascaris suum* Eggs on Tomatoes Under Field Conditions

Time after Spraying (days)	Eggs per Tomato	Weight of Tomatoes (g.)	Eggs at Harvest[1]	Eggs after Incubation[1]
1	3,700	102	———	96% ME, 2% EM or LM, 2% U or D
1	3,400	40	———	93% ME, 4% EM or LM, 3% U or D
13	965	124	100% U or D	23% ME, 17% T, 6% EM or LM, 55% D
13	950	107	99% U or D, 1% EM	11% ME, 13% T, 5% EM or LM, 2% U, 69% D
19	760	78	78% D, 2% U, 3% EM or LM, 17% I	2% ME, 2% T, 2% I, 94% D
19	665	100	———	4% I, 96% D
27	290	200	100% U or D	100% D

[1] Abbreviations used: D—degenerate or empty egg shells; U—unicellular eggs; EM—early morulas (2 to 16 cells); LM—late morulas (16 cells to incurved morula); T—tadpoles (incurved morula to motiles); ME—motile embryos; I—intermediate (either degenerate or late morula).

combined with the antiformin. This liquid, containing any eggs present, was centrifuged and the residue washed by centrifugation to remove most of the antiformin. The sediment was taken up in 5 or 10 ml. of water, one ml. being examined for *Ascaris* eggs, the remainder being incubated for 10 to 14 days at 30° C. for viability tests.

Field Experimentation Results

These experiments were conducted during 1949. A suspension of *Ascaris* eggs isolated from adult worms was mixed into a thin feces suspension in a Waring blender. This suspension contained approximately 20,000 eggs per ml. Tomatoes and lettuce growing in the field were heavily sprayed with the suspension. The tomatoes selected were those protected as much as possible by overlying leaves. At intervals, samples were taken for *Ascaris* assays as described above. The condensed results obtained for tomatoes are shown in Table I; for lettuce, in Table II.

TABLE II.—Survival of *Ascaris suum* Eggs on Lettuce Under Field Conditions

Time after Spraying (days)	Eggs per Plant	Eggs at Harvest[1]	Eggs after Incubation[1]
3	17,250	16% D, 46% U, 38% EM	59% U or D, 8% EM, 21% LM, 4% T, 8% ME[2]
19	10,300	99% U or D, 1% EM	93% U or D, 3% EM, 1% T, 3% ME[2]
35	3,150	100% D	100% D

[1] Abbreviations same as in Table I.
[2] Embryos thin and abnormal, not active.

On tomatoes, the initial egg concentration was about 3,500 per tomato. This had been reduced to some 290, or approximately 10 per cent, in 27 days. Of course, the conditions of the eggs had materially changed. One day after spraying almost all the eggs were viable, developing to motile embryos after further incubation. After 13 days, no development of the eggs had taken place in the field. Subsequent incubation showed that most of the eggs had been killed, but 26 to 45 per cent were still viable and developed to varying stages. The predominance of intermediate developmental stages after incubation indicated that the eggs which did not completely develop were possibly affected in some way by field exposure so that, although viable, they could not develop as fast as normal or they could not develop beyond a certain point and would never reach the infective stage.

Examination of the development of the eggs when the crop was harvested indicated that only a very small percentage had begun to develop toward the embryonic stage. In no case were

infective motile embryos found to have developed on the plant surfaces in the field. By the 27th day, all eggs found were degenerated or were incapable of development. If any had begun to develop or even were completely developed by this time, they must have degenerated.

The experiments on lettuce show similar results. After three days, 38 per cent of the eggs had developed to the early morula (2 to 16 cells) stage. Subsequent incubation, however, showed that 59 per cent of the eggs were incapable of development. The motile embryos which did form were abnormal, appearing thin and very sluggish. After 19 days the number of eggs per plant was still high, but more than 99 per cent were degenerate or undeveloped. Those which were developed had only progressed to the two-cell early morula. Thus, it appears that if eggs had developed to later stages, as was found after 3 days, then they must have subsequently degenerated by the 19th day. Of the eggs found on the 19th day, a small percentage developed to the motile stage on subsequent incubation. Such was not found to be the case for tomatoes in the field 19 days after contamination.

Discussion

In the light of the work of previous investigators on the comparatively great resistance of *Ascaris* eggs to the external environment in soil and feces, the results of the present work on their survival on the surfaces of vegetables growing in the field are of interest. Although a reduction in numbers of eggs takes place, due either to washing off by rain or to disintegration of the eggs during weathering, it is apparent that plants such as tomatoes or lettuce will not completely free themselves in one month's time of contaminating *Ascaris* eggs applied to their surface. In the case of lettuce, certainly, this period of time may be sufficient to allow a complete maturing and harvesting of the crop.

Although it may take a long time to rid a vegetable of *Ascaris* eggs, if it can be done at all by natural processes, there appears to be a marked deleterious effect on the viability of the eggs when exposed on surfaces of tomatoes and lettuce in the field. In no case were the eggs found to have developed to the infective motile embryo stage. The development of the eggs upon incubation showed that viable eggs were present on the vegetable surfaces for approximately 3 to 4 weeks after deposition. It must be borne in mind that the field conditions under which these experiments were carried out were those of a dry hot summer for the area. Whether or not similar results can be obtained under more moist conditions which might prevail in tropical areas of the world, where intestinal helminth diseases are more prevalent, is open to question. Desiccation has been shown by investigators to be one of the greatest lethal factors to the development of these eggs. The climatological aspects of a location with respect to moisture may thus become important in determining the rate of development of *Ascaris* or other helminth eggs.

Conclusions

Certain conclusions have been drawn on the basis of the field work conducted with *Ascaris* eggs, as follows:

1. *Ascaris* eggs sprayed on lettuce or tomatoes show a reduction in numbers with time, but not at such a rate that the plant will free itself from the eggs in one month. Lettuce with a comparatively short growing season could carry eggs through to the harvest.
2. Development of the eggs is greatly retarded in the field.
3. Completely developed eggs containing motile embryos, which are required for infection, were never found on the field vegetables examined when undeveloped eggs were sprayed on them. It is probable that retardation in development was accompanied by decreased resistance to the external environment.

4. The exposure of undeveloped eggs to field conditions on vegetable surfaces greatly reduces the viability of the eggs, the majority being unable to develop satisfactorily, if at all, under subsequent optimum incubation conditions.

5. The resistance of *Ascaris* eggs on vegetable surfaces such as those of lettuce or tomatoes under field conditions is probably much less than might be expected from consideration of the resistance of these eggs in soil, feces, or night soil.

Summary

Field experiments on the survival of *Ascaris suum* eggs were conducted by spraying suspensions of *Ascaris* eggs and feces on growing tomatoes and lettuce. Plants and fruit were harvested at intervals. Results show that a reduction of the number of eggs took place with time, but some eggs remained on the plants and fruits for more than a month. Development of eggs was greatly retarded and completely developed eggs containing motile embryos required for infection were not recovered. The exposure of undeveloped eggs to field conditions reduced greatly the viability of the eggs. It appears that resistance of *Ascaris* eggs on vegetable surfaces is less than might be expected from considerations of their resistance in soil, feces, or night soil. All eggs degenerated after 27 to 35 days and were incapable of development for infection.

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Stream Pollution

NATURAL REDUCTION OF PAPER MILL COLOR IN STREAMS *

By M. A. Churchill

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Importance of Color

In the mountainous headwaters of the Tennessee River, the streams—as might be expected in such an area—are for the most part clear. This is a region of national forests and national parks. The Great Smoky Mountains National Park, the numerous large reservoirs developed by TVA, and, more recently, the atomic bomb project at Oak Ridge, have all resulted in a flourishing tourist business for the area as a whole. As is well-known, clear streams and lakes are very attractive, especially at vacation time, whereas muddy or colored waters are quite the opposite.

The clear streams of this area have attracted a number of paper mills and other industries to which clear water is desirable or essential. However, downstream from a number of these mills the water is highly colored.

In the Tennessee Valley there is a growing consciousness that pollution by color is perhaps the worst kind of pollution in this area as far as public reaction is concerned. Low concentrations of dissolved oxygen, high B.O.D. values, and high coliform concentrations are certainly undesirable, but cannot be seen in a stream. Besides, these evidences of pollution are ordinarily removed by natural purification processes in a relatively short distance in the turbulent streams of the mountain section. Color, on the other hand, persists for distances up to 150 mi. in certain rivers in the Tennessee Valley. The French Broad, the Pigeon, and the Little Tennessee Rivers are all seriously polluted with color from paper mill wastes.

Objective of Color Pollution Study

One of these streams, the Little Tennessee River, has been selected for the study of color pollution. This report covers the observations made during the latter part of 1948 and the whole of 1949.

The principal objective of the study is to determine if the high colors observed in the streams below the paper mill are merely reduced farther downstream by dilution with relatively clear local inflows or if there is in addition some reduction in color due to other natural processes, such as bleaching.

Source of Color Pollution in Little Tennessee River

The Little Tennessee River and its tributaries drain a mountainous region of western North Carolina and eastern Tennessee, as shown in Figure 1. Near the headwaters of the principal tributary, at Sylva, N. C., is located a semi-chemical pulp and paperboard mill.

Currently this mill uses daily 17,600 cu. ft. of chestnut wood, 7,200 cu. ft. of mixed woods, and 15 tons of old corrugated paperboard boxes. Its average daily production is 66,000 lb. of 25 per cent tannic acid, and 145 tons of 9-point paperboard, which is used in the manufacture of corrugated paperboard boxes.

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Washington, D. C.; October 9–12, 1950.

FIGURE 1.—Sampling stations for color pollution study of Little Tennessee River and tributaries.

The wood is chipped, the chips are autoclaved to extract the acid, and are then charged into the digesters for cooking. To each digester is added sodium sulfite, soda ash, and water. The charge from the digesters is pulped in two stages and pumped without washing to the paper machines. There is no chemical recovery.

The principal sources of color are the black liquor from the digesters and the white water. A tannery also located at Sylva discharges some color, but this is very minor in comparison to that of the mill. There are no other industrial sources of color pollution in this watershed.

Sampling Program

Samples were collected twice a month from each of 14 stations (Figure 1). Six of the stations were located along the line of flow of the waste from the mill, the first such station being only 4.4 mi. below the mouth of the small stream, Scott Creek, which receives the plant waste directly, and the last station being some 88 mi. downstream from the mouth of Scott Creek. One station is located on the Tuckasegee River just above Scott Creek, and the remaining seven stations are on tributaries. This last group of stations was established to determine the color characteristics of the water available for dilution of the mill waste.

Procedure for Measuring Color

In the laboratory the samples were flocculated with calcium chloride and/or centrifuged to remove all turbidity without affecting the true color of the water.

Measurement of color by visual comparison of samples with prepared standards is not consistent or accurate. To obtain both consistency and accuracy, the samples were examined with a Fisher electrophotometer. This machine is so constructed that a mirror

splits the light beam from a single source. Half of the beam is passed through the sample to a photocell and the other half is reflected by the mirror to a matching photocell. The effect on light transmission of the transparent sample container itself (plus the mirror and filter) is removed by using a distilled water sample in a matching sample container, for which condition the electrophotometer is set to read 100 per cent transmission. To obtain maximum accuracy on relatively clear samples a rectangular sample container is used which requires the light beam to pass through 50 mm. of sample.

Maximum sensitivity and accuracy is achieved if the incident light is passed through a filter ahead of the mirror and sample, the particular filter being selected for use that has its maximum transmission in the wave length region in which there is maximum absorption by the colored solution. For the samples under study, the selected filter was green, having its maximum transmission at a wave length of 525 mμ.

Because it was desirable to relate the percentage of light transmitted to the relative concentration of color-producing material in the samples, a color solution was made up in the manner prescribed by Standard Methods (1) excepting that 1.245 g. of potassium chloroplatinate only, without the prescribed 1 g. of cobaltous chloride, was dissolved in 1 l. of acidified water. The resulting color concentration was assigned a value of 500 units of relative color concentration, not color. The name "relative color" was used to distinguish this solution from the standard platinum-cobalt solution ordinarily used and prescribed by Standard Methods.

The percentage of light transmitted through this strength of relative color solution is 83.9 using a green filter. It was found upon experimentation with various dilutions of this solution that if observed values of percentage transmission were plotted along the logarithmic scale of semilogarithmic paper, against relative color concentrations, along the arithmetic scale, the resulting plot was very nearly a straight line. This is a rather common characteristic of colored solutions, an exactly straight line indicating the solution follows the Lambert-Beer law.

Experimentation with dilutions of highly colored samples from Scott Creek showed the diluted mill wastes also follow the Lambert-Beer law, at least within the experimental range. The following table gives in very brief form values from the calibration curve showing the relation of per cent transmission, using the green filter, to relative color concentrations as used in this study:

Light Transmitted (%)	Relative Color Concentration (p.p.m. Pt)
100	0
95	125
90	270
85	455
80	650

In order for the reader to obtain some idea of the relation between the values of relative color as discussed in this report and values on the standard platinum-cobalt scale, a series of samples of diluted digester liquor were examined with the electrophotometer and also compared visually with platinum-cobalt standards. It was found, in general, that relative color values were about five times the color (platinum-cobalt) values.

Analysis of Observed Data

Effect of River Discharge on Observed Color

As would be expected, it was found early in the study that at stations 2 and 4 (Dillsboro and Bryson City, respectively) there is a definite and consistent reduction in relative color concentration with increased flow in the Tuckasegee River. Mixing in Fontana Reservoir below Bryson City, and the complete regulation of discharges at the dam, prevent any such relation between relative color concentration and

TABLE I.—Mean Daily Discharges, Relative Color Concentrations, and Light Transmittals

Station		Daily Discharge (c.f.s.)	Relative Color Conc. (p.p.m. Pt)	Light Transmitted (%)
No.	Location			
1	Tuckasegee R. above Scott Creek	1,000	113	95.5
2	Tuckasegee R. near Dillsboro	1,150	444	85.3
3	Oconaluftee River	650	75	97.0
4	Tuckasegee R. near Bryson City	2,220	256	90.5
5	Little Tenn. R. above Fontana Res.	1,550	152	94.0
6	Nantahala R. above Fontana Res.	585	55	97.8
7	Little Tenn. R. at Fontana Dam	5,480	94	96.3
8	Little Tenn. R. at Cheoah Dam	6,080	74	97.1
9	Cheoah R. at Santeetlah P. H.	740	61	97.6
10	Little Tenn. R. at Calderwood P. H.	6,450	77	96.9
11	Little Tenn. R. above Tellico River	7,230	125	95.0
12	Nine Mile Cr. below Calderwood	—	167	93.5
13	Abrams Cr. below Calderwood	—	69	97.3
14	Hazel Creek above Fontana Dam	—	44	98.3

discharge from being established at Fontana Dam or any other downstream station.

Each of the tributary stations showed only a "buckshot" relation between flow and relative color. No seasonal effects could be detected either.

Retention in Fontana Reservoir

Fontana Reservoir being so large (1,444,300 acre-ft. of storage, 10,670 acres of surface area, and 450 ft. of depth at the dam when full), it provides a long period of retention for the inflowing water. To evaluate the effect of the reservoir on color reduction, if any, it is necessary to be sure that observations and calculations are made on the same water going in as coming out of the reservoir. To do this the period of retention was computed for the water discharged from the dam on January 1, 1949, and also for that discharged December 31, 1949. In both cases, the period of retention was found from daily discharges and pool volumes to be about two and one-half months. Consequently, it was determined that all the water entering the pool between mid-October, 1948, and mid-October, 1949, was discharged from the dam during the calendar year 1949. Therefore, mean color concentrations and river flows above the reservoir were computed for the year mid-October, 1948, to mid-October, 1949, for comparison with similar values below the dam for the calendar year 1949.

Due to thermal stratification in Fontana Reservoir during the summer months and to the high pool level in the summer, water entering Fontana Reservoir in the spring of the year is retained for perhaps six months before being discharged.

Cheoah and Calderwood Reservoirs, below Fontana, are both relatively small. Therefore, no attempt was made to shift the periods of computations to take their periods of retention (less than a week combined) into account.

Computation of Mean Relative Color Concentrations

At stations 2 and 4, the ones showing a relation of relative color to discharges, daily river discharges were multiplied by the relative color concentration established for that discharge by the relation referred to above. These daily products were added for each station for the entire year, mid-October, 1948, to mid-October, 1949, and the sum divided by the total flow during this period. The result was a weighted mean relative color concentration of 444 at station 2 and of 256 for station 4.

For each other sampling station above Fontana Reservoir the individual results of the relative color determinations made on the semi-monthly samples were simply averaged (since no relation of relative color to flow was found) for the year mid-October, 1948, to mid-October, 1949. Similarly, results were averaged at each station below Fontana Dam for the calendar year 1949.

Mean percentages of light transmitted were determined for each of these lower stations by reading the value on the established calibration curve for the electrophotometer corresponding to that of the mean relative color concentration as determined above.

Results Obtained

Observed Color Concentrations

Using the methods explained in the preceding paragraphs the mean relative color concentrations and percentages of light transmitted were determined for the year applicable to each station (Table I). These results are plotted for the stations along the line of flow of the mill wastes in Figures 2 and 3.

Between stations 1 and 2, Scott Creek, carrying the mill wastes, raises the relative color concentration from 113 to 444. Correspondingly, the transmittancy is reduced from 95.5 to 85.3 per cent. At this point it should be noted that although water having a transmittancy of 95.5 per cent appears quite clear in a stream, water having a transmittancy of 85.3 per cent appears anything but clear, in fact it is very dark and obviously seriously polluted by some industrial waste. In addition, the stream at this point is well supplied with streaks and patches of foam resembling soap suds.

At Bryson City the water is still very dark, although at this location the river flow has doubled. The Tuckasegee River arm of Fontana Reservoir, and sometimes part or all of the main pool below this point, has a dark cast somewhat resembling the water found in the swamps of Florida.

By the time the water is discharged through the deep intakes of the power units in Fontana Dam the waste has been diluted some five times more than at Dillsboro. The water at this point usually, but not always, has about the same transparency as natural unpolluted surface water in this area, but the shade of remaining color is noticeably different from that of unpolluted

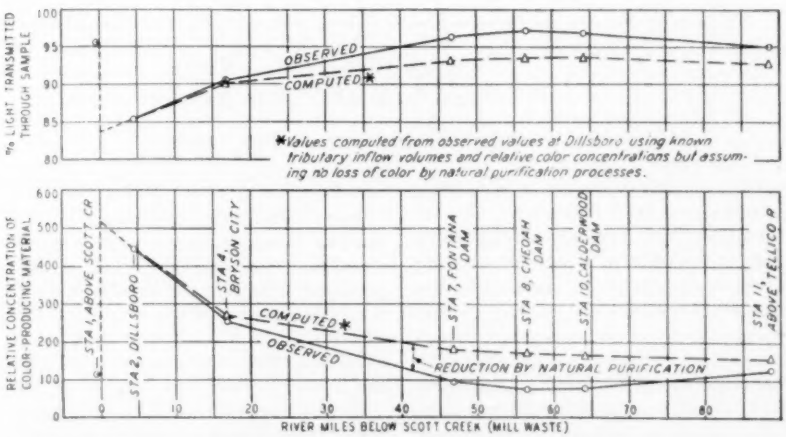

FIGURE 2.—Color of Tuckasegee and Little Tennessee Rivers below paper mill.

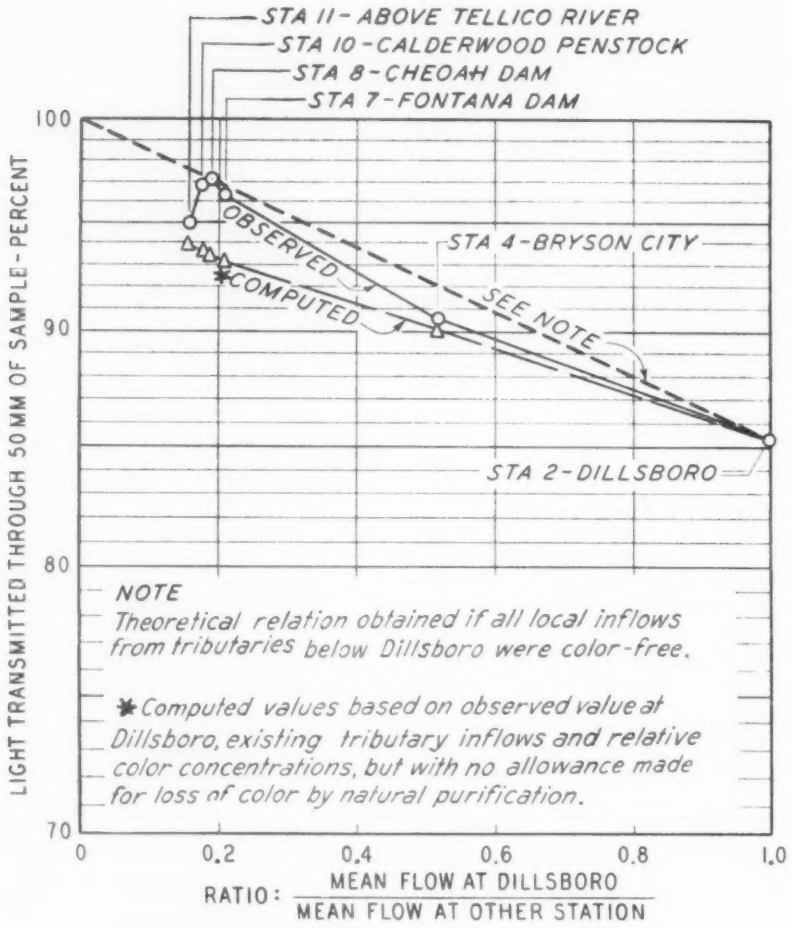
STA 11 - ABOVE TELLICO RIVER
STA 10 - CALDERWOOD PENSTOCK
STA 8 - CHEOAH DAM
STA 7 - FONTANA DAM
STA 4 - BRYSON CITY
OBSERVED
COMPUTED
SEE NOTE
STA 2 - DILLSBORO
LIGHT TRANSMITTED THROUGH 50 MM OF SAMPLE - PERCENT
100
90
80
70
0
0.2
0.4
0.6
0.8
1.0
RATIO: MEAN FLOW AT DILLSBORO / MEAN FLOW AT OTHER STATION
NOTE
Theoretical relation obtained if all local inflows from tributaries below Dillsboro were color-free.
* Computed values based on observed value at Dillsboro, existing tributary inflows and relative color concentrations, but with no allowance made for loss of color by natural purification.

FIGURE 3.—Effect of dilution in river on light transmitted.

waters. Downstream from this point the unnatural shade fades gradually, the foam thins out, and below Calderwood Dam it is doubtful if anyone viewing the river at this point, and unfamiliar with its appearance upstream, would realize that it is abnormal. It should be noted that the flow of the river at this point averaged 6,450 c.f.s. during 1949. This flow is about 50 per cent higher than the mean annual flow at Calderwood of 4,193 c.f.s.

Computed Color Concentrations

In an attempt to determine the reduction in color concentration brought about by bleaching and other natural processes, relative color concentrations were computed in a downstream direction for each line-of-flow station below Dillsboro, with results as shown in Figure 2.

In this computation the products obtained by multiplying successive local inflow volumes for the year by corre-

sponding relative color concentrations were added to similar products for the main flow, and the weighted mean color concentration computed therefrom for each station below Dillsboro along the line of flow of the mill wastes. The differences noted in Figure 2 between the computed and observed values are due to the cumulative removal of color by natural purification processes.

Due to the basic similarity between the nature of the natural color in the streams and of the mill wastes, it is felt that any attempt to compute their separate reductions in the river would be unjustified. The reductions shown are total cumulative reductions in the combined natural and pollutional color concentrations as computed in a downstream direction starting with observed values at Dillsboro.

It should be noted that the major reduction occurs in Fontana Reservoir. The computed mean relative color concentration of all the water entering the pool is 179, but is only 94 for the water discharged from the dam. As but very little of this difference (10 units to be exact) is noted at Bryson City upstream, practically all of the 50 per cent reduction occurs in the reservoir. A slight reduction occurs in Cheoah Reservoir, but Calderwood shows no improvement. Below Calderwood local inflows are higher in natural color than the water in the main stream so at the most downstream sampling station the water is slightly darker than at Calderwood.

Figure 2 shows that at Fontana, Cheoah, and Calderwood Dams the actual concentration of color producing material is only about half what would have existed had no natural purification occurred. It is interesting to note that although the computed concentration is roughly 100 per cent greater than the actual color concentration, the difference in corresponding transmittancies is only some 3.5 per cent. In other words, in relatively clear solutions a large percentage change is required in the concentration of colored material before any appreciable change in percentage transmission is produced. That this is true is evident from Beer's law, which states that the negative logarithm of the transmittancy varies as the concentration of the substance. For example, for a solution showing a transmittancy of 0.900 (90 per cent) the negative log of the transmittancy is 0.0458. A solution having only half the concentration of this solution would, therefore, have a negative log of transmittance of 0.0229 and a corresponding transmittancy of 0.949 (94.9 per cent).

The same line of reasoning applies to very dark solutions as well as to very light ones; that is, a large percentage change in concentration is required before any appreciable change in transmittancy is obtained. Beer's law shows this, of course, as a little calculation will prove. Furthermore, a strong dye (or digester liquor) solution, and the same solution diluted with an equal volume of water, will appear to the eye to have exactly the same intensity of color. In the middle range of transmittancy, however, a large percentage change in concentration of the colored substance also produces a relatively large change in the transmittancy. For solutions to which Beer's law can be applied, the quantitative effect on light transmission of both increasing and decreasing the concentration of color producing material is shown by Figure 4. For example, if a sample of highly colored mill waste water allows a transmission of, say, 10 per cent and if this sample were diluted with an equal volume of colorless water, the increase in transmission would be 21.6 per cent. Therefore, the diluted sample would show a transmission of 31.6 per cent, but to the eye the original and the diluted sample would appear identical—black. Correspondingly, if a stream is so highly colored as to appear black at the location under observation, an increase in color producing material of as much as several hundred per cent cannot possibly

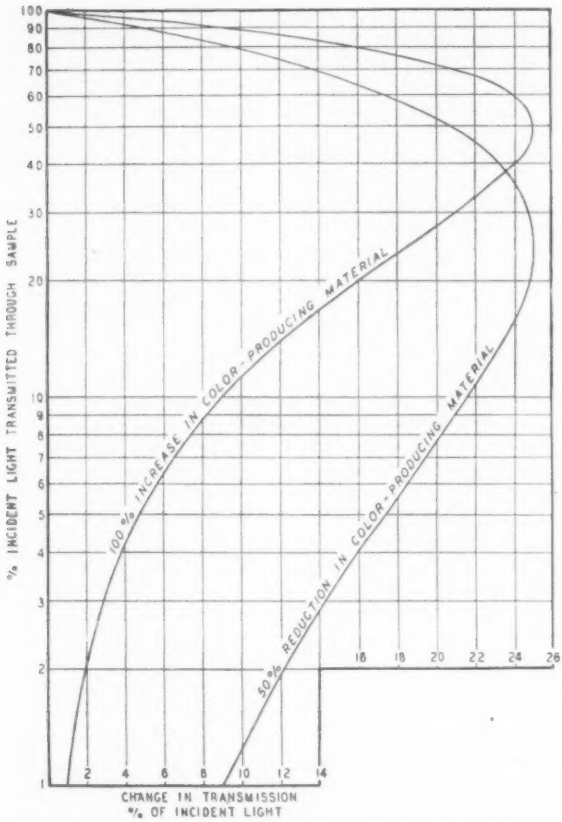

FIGURE 4.—Theoretical effect on light transmission of changing concentration of color producing material.

change its appearance appreciably at that location. Obviously, however, such an increase would affect the river's appearance adversely at points farther downstream.

It is a matter of personal opinion at just what value of light transmission a mill waste stream appears black, but it is quite certain that most people would agree that a stream is black when a sample of it transmits any less than 80 per cent of the incident light, as measured in this study. Consequently, any reduction in color producing material that does not result in transmissions materially greater than 80 per cent at the river location in question will go unnoticed and unappreciated by the public. Even 80 per cent transmission is, of course, not nearly enough to satisfy the general public in clear-stream sections of the country such as the Tennessee Valley.

The 50 per cent reduction curve of Figure 4 can be used to determine the approximate dilution or reduction in color producing material necessary to produce any desired transmittancy in the final dilution. This is done by entering the curve with the initial value of transmittancy, reading the increase in transmittancy obtained by a 50 per

cent reduction in waste on the abscissa scale, adding this increase to the initial transmittancy value, and then repeating the process with the new values thus obtained until the desired transmittancy is reached. It is somewhat simpler, of course, to compute the reduction required by the direct application of Beer's Law.

Reduction Required to Render Color Unobjectionable

An inspection of Figure 3 will show that if the strongly colored water at Dillsboro just below the mouth of Scott Creek could be diluted with local inflows having no color at all, 95 per cent transmittancy (corresponding to the color of some of the natural unpolluted streams in this area) would be reached when the ratio of the Dillsboro flow to the total flow is about 0.3. With a Dillsboro flow of 1,150 c.f.s. the corresponding total flow after dilution would be nearly 4,000 c.f.s.

Although the actual local inflow below Dillsboro is not entirely free of color, natural purification so reduces both the color added by the paper mill and by natural sources that at Cheoah Dam the actual color concentration is no greater than would result at Dillsboro from diluting the 1,150 c.f.s. of colored water at Dillsboro with 4,930 c.f.s. of colorless water. At Cheoah Dam the average flow for the year was 6,080 c.f.s.

Based on a production of 145 tons per day of paper, a flow of 6,000 c.f.s. is the equivalent of 42 c.f.s. of diluting flow per ton of paper produced.

Any attempt to estimate how much color producing material the mill could release into the Tuckasegee River at Dillsboro without producing an adverse public reaction at that location must be based upon an assumption of how much of an increase in the color of the river would "get by" the public. The eye is fairly sensitive to color intensity changes in the range of 95 per cent transmittancy, particularly if the shade of color is at all unnatural. It is quite certain that if the transmittancy were decreased from the observed value of 95.5 above Scott Creek to 92.5 below the creek many people would notice the change. However, using this value as only a fair approximation of the limiting value, it is computed that the mill could discharge only about 30 per cent of the color producing material that is now being discharged. Furthermore, this value is based on 1,150 c.f.s. of stream flow at Dillsboro, and consequently, during periods of low flow much less material could be released.

Some appreciation of the enormous dilutions required to produce water in the river having a transmission of 92.5 per cent is obtained when it is realized that about 350 p.p.m. of digester liquor will produce this transmission in distilled water. This dilution is 2,860 to 1.

The nature of the receiving stream has an effect on the apparent color of the water, inasmuch as water in deep pools appears much darker than the same water flowing over shoals. This is true not only on account of the "white water" produced by the rapids, but also because in deep pools more depth of water is available to absorb the incident light.

In a relatively clear water transmitting 95 per cent of the incident light through the upper 50 mm. of depth, 95 per cent of the remaining light intensity will be transmitted through the second 50 mm. of depth, and so on. To reduce the light intensity to 10 per cent of its value at the water surface would require a depth of 7.5 ft. On the other hand, in water transmitting only 85 per cent of the incident light a depth of only 2.3 ft. would reduce the light intensity to 10 per cent of its surface value.

Summary

Semichemical pulp and paper mill wastes are highly colored and in the Tennessee Valley render many miles of otherwise clear streams quite dark and objectionable to the observer. In the

open rivers the only significant reduction in color concentration is produced by dilution, but in a large storage reservoir a material reduction by natural purification processes occurs.

In the case of the river system studied, a diluting flow equal to about 40 c.f.s. per ton of paperboard produced, plus considerable natural purification in a large storage reservoir, is necessary to reduce the color to what might be considered as natural for river water in this area.

Acknowledgments

This study was made under the general direction of R. N. Clark, chief, Public Health Engineering Branch, and under the supervision of F. W. Kittrell, chief, Stream Sanitation Section.

Samples were collected from the upstream six stations, through the courtesy of J. R. Buchanan, manager, Sylva Division, The Mead Corporation, by personnel of the Sylva Division. At three of the dams, samples were collected by operating personnel of the Aluminum Company of America, and at Fontana by TVA operating personnel. Samples from the remaining stations were collected by local residents under contract.

In the laboratory the samples were examined by Stream Sanitation Section personnel under the supervision of W. F. Vaughan, chemist, who with L. R. Setter set up the procedure for determining relative color concentrations based on the color produced by platinum only in solution. Following the suggestion of the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) the data on relative color were interpreted in terms of percentage of light transmitted.

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DISCUSSION *

By William D. Hanlon

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The full importance of stream color pollution probably was not realized in this country until the most recent years. Mr. Churchill has come in contact with this problem and as a result has emphasized two important facts. These are: (1) Unlike other types of pollution, color can actually be seen by the public; and (2) color pollution may persist for many times the distance that is normally required for stream purification.

During the last three years, stream color pollution has been investigated by the Department of Sanitation, Rutgers University, and many data have been accumulated.

One of the preliminary problems encountered in solution color determination is that of removing the suspended material, which can make a great difference in the light transmission characteristics of a colored solution. The physical characteristics of suspended materials are generally changed with biological purification. As a result, an apparent change in solution color may actually be a change in the degree of light absorption by the suspended material. It is difficult to remove colloidal material by normal centrifuging, and the value of chemicals for this purpose is also questionable. For example, it has been found that various salts and pH values will effect a change in the color characteristics of rag paper and sulfite cooking liquors. Filtration

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

is probably the best means of clarification, but with this method the possibility of color adsorption by the filtering medium must be considered.

Mr. Churchill noted that color measurement by visual comparison with prepared standards is not accurate. This is reasonable, as there is considerable variation in the sensitivity of the human eye, and a large number of readings is required before a mean value can be determined.

If solution light transmission characteristics follow Beer's Law, it is possible to convert laboratory data to the effect that will be realized in stream waters which are of greater depth than the absorption cell length. It is interesting to investigate the variation in light transmission with depth of solution. Mr. Churchill mentioned that water having a transmittancy value of 95.5 per cent appeared quite clear in a stream, whereas water having a transmittancy value of 85.3 per cent appeared highly colored. The difference in transmittancy for the 50-mm. absorption cell data is only 10.2 per cent. When these transmission characteristics for the same two waters are calculated to greater water depths, we find interesting results. For example, the solution with a 50-mm. cell transmittancy of 95.5 per cent would have a transmittancy value of 75.5 per cent when the absorbing medium is 1 ft. thick. On the other hand, the sample with a transmittancy of 85.3 per cent, would have a 1-ft. transmittancy value of only 37.9 per cent. The difference in light transmission for the greater depth would be 47.4 per cent. The two original waters (95.5 and 85.3 per cent transmittancy) had a transmittancy difference of only 10.2 per cent in the 50-mm. absorption cells. This difference in transmittancy would be small when compared to the transmittancy difference (47.4 per cent) obtained when the transmission values were calculated to the greater depth. This example shows why light absorption increased relatively more in the 85.3 per cent transmittancy water than in the 95.5 per cent water and may help to explain why the water with a 50-mm. cell transmittancy of 85.3 per cent appeared so dark under actual stream conditions.

The fact must also be considered that in stream waters light must pass through the absorbing medium more than once before it reaches the eye of the observer. Mr. Churchill mentioned that the nature of the receiving stream will make water in deep pools appear much darker. This may be true when such factors as vegetation, bottom material, and light conditions affect the appearance. However, it is probable that the darker appearance is for the most part a result of increased depth, and it is advisable to survey the stream depth as well as the other factors mentioned when evaluating the pollutional effect of a highly colored waste.

Mr. Churchill found that dilution was one of the most effective means for stream color reduction. Color reduction by natural processes was noticed, but required a long time. The natural color reduction can probably be attributed to a combination of such factors as sunlight, biological action, and sedimentation. It was also shown that the results obtainable by dilution can be calculated; this is important to stream pollution problems.

Many factors should be considered in any attempt to determine the specific concentration of waste which will be unsightly in stream waters. These are: depth of water, light absorbing characteristics of the water and the stream bottom, turbidity, light source, hue, and angle of observation.

This paper has brought forth several interesting points, which should be helpful to the solution of similar color pollution problems. At the same time, it emphasizes the beginning of a comparatively new and important study in the field of stream sanitation.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

OPERATORS' LICENSING BILL BEFORE IOWA LEGISLATURE

A "Sewage Treatment Plant Operators' Licensing Bill," to be presented to the forthcoming session of the Iowa Legislature under the sponsorship of the Iowa Sewage Works Association, provides for the operation of sewage and industrial waste treatment plants in the state by licensed operators or superintendents and creates an examining board for administration of the licensing program. The program is expected to be financed by licensing fees and no appropriations are requested.

Among the salient features of the bill, which is an outgrowth of recommendations submitted to the Association in October, 1947, by a special committee composed of C. O. Alexander, W. E. Galligan, and Paul Bolton, are the following:

1. Establishment of a three-member Examining Board, including a sewage treatment plant superintendent or operator, a consulting engineer in the sewage and waste treatment field, and a municipal official. The director, Division of Public Health Engineering, Iowa State Department of Health, or his designated staff member, will serve as executive secretary of the Board.

2. Examinations for the purpose of determining the qualifications of applicants for licensing as superintendents or operators are to be held a minimum of two and a maximum of four times annually.

3. The customary "grandfather" clause, in this case extending to those certified by the employer as having been employed as a superintendent or operator-in-charge of a plant for six months prior to the effective date of the Act.

4. A $5 annual license fee.

5. Revocation of any license for certain established offenses, after a hearing before the Board, with ineligibility for re-examination for periods from six months to two years.

6. Fines ranging from $100 to $500, or six months imprisonment, or both, for unlicensed operation or employment of an unlicensed operator.

Home Study Courses

Although specific operator qualifications for licensing are made the province of the Examining Board established by the Bill, the 1947 committee report outlines arrangements with the Engineering Extension Service, Iowa State College, for a series of academic courses of instruction. The courses, stressing the basic fundamentals and a knowledge of the functions and mechanics of sewage treatment, are designed to be carried on by correspondence as a series of supervised home study courses. Exemption from certain of the courses would be provided by approval of the Examining Board upon request of qualified operators. Completion of the series, or the equivalent was recommended as one of the requisites for licensing.

[Note—On January 17, 1951, a "Bill for the Certification of Water and Sewage Works Operators" was introduced into the Indiana State Legislature and referred to the Committee on Public Health.]

1950 OPERATORS' FORUM *

C. C. LARSON, *Leader*

Public Relations

Walter A. Sperry, Superintendent, Aurora (Ill.) Sanitary District:—I was slightly embarrassed when asked to speak on public relations, because that extremely important phase of plant administration seemed so well rooted in all our philosophies and operations that it hardly seemed necessary to go over it again. However, reference to the 20-Year Index of the Journal shows a rich fund of public relations material available. Much of this material apparently has been forgotten with the passage of time.

In my own thinking public relations is merely the desire to be helpful. Its purpose is to attain and create public confidence and good will toward the operating institution. It is a compound of a sure knowledge of your art, a job well done at the plant, a smattering of patience, a liking for people, some courtesy of disposition, an ability to write and speak, a sense of humor, and a smattering of sympathy.

I remember well the advice of a man who had been secretary in one Board of Health office for many years. His public relations formula consisted of letting the irate complainant get his pet peeve off his chest, then questioning him in such a way as to get him to tell the whole story again and maybe a third or fourth time until the "pressure" was relieved. Then and only then did he attempt to talk the whole thing over. This procedure involves patience and a sympathetic understanding of the complainant's viewpoint, as well as a lot of things not very enjoyable to most of us. It is, however, a necessary function of an administrative position.

On the basis of the preachers' rule of thumb that any sermon more than three years old can be re-used without anyone recognizing it, I want briefly to mention a series of four editorials * in *Sewage Works Journal* outlining a simple formula for good public relations. The first is headed "A Job Well Done." It is obvious that if a plant is not in good order, if a good job isn't being done, and if the plant isn't performing as it should, there is no justifiable basis for public relations. If the plant is a source of nuisance to the public you haven't a leg to stand on.

The second item is on "Personal Courtesy." It is extremely easy to be unintentionally curt with complaints or requests for information, particularly if they should be properly directed to another agency or office. Also, it is of utmost importance to always be aware of the possibility of unintentionally offending the unseen person at the other end of a telephone call. The courteous, helpful attitude may be hard to summon up near the end of a trying day, but it will make a friend—and its lack will create a resentment—just as readily then as early in the morning.

Personal courtesy may not always mean direct contact with the recipient. For example, at the entrance to our plant is a printed paragraph signed by the superintendent. It reads:

"To the visitor:

The Trustees welcome you as a visitor to your plant. You are free to inspect the entire plant. It is suggested that you first study the pictured operation chart on the upper gallery to see just how it works. After this you will

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Washington, D. C.; Oct. 9–12, 1950. The first section of this Forum, covering "Sampling Technique" and "Lubrication of Equipment," appeared in THIS JOURNAL, **23**, 4, 541 (Apr., 1951).

* *Sewage Works Journal*, **17**, 6, 1234 (Nov., 1945); **18**, 1, 88 (Jan., 1946); **18**, 2, 288 (Mar., 1946); **18**, 3, 527 (May, 1946).

find statements in each part of the plant explaining that portion."

This is more than a welcome: it is an implied statement that the citizen-taxpayer is a stockholder in that particular institution. It is also an admission that he has the right to visit, the right to ask questions, and the right to be given answers. Many other examples of this type of indirect courtesy could be cited.

The third item is on "Constructive Publicity." Of course, that suggests several things. It suggests a friendliness with the local papers; also, an ability to write. If and when there is something you think the public should know, write the article yourself. That way, you get in everything that's needed—and in the proper order. One of the most awkward situations that can arise is to have a paper mess up a perfectly good statement by misinterpreting it.

The last of the four editorials is on "Civic Leadership." I have always felt it invaluable for plant superintendents and other officials to be members of some local service club and to take part in other public activities as time and opportunity permit. I have had the privilege of speaking before all five luncheon clubs in our city three times around, which bears its own implication that maybe I was fortunate in having them enjoy what I said. In any event, it has been a marvelous and worth-while opportunity to display and explain the function of our particular work in the community's daily life.

In June, 1950, the local Kiwanis Club devoted one meeting to a testimonial dinner honoring the work of the Sanitary District on its silver anniversary. It was an exceedingly happy occasion, with the largest representation of local official "brass" ever assembled at such an affair in the city. That occasion really "caught on" with the local paper, which came out with 51 in. of text and 31 in. of double column editorials in two issues! The whole affair was a complete expression of the good will we have earned in the community. One editorial event went so far as to say that it was "agreed that the accomplishment of the District rates with the top works for public good in the 113 years of Aurora history." This, of course, was very gratifying to those of us connected with the work. Most important, however, was its value in putting the District's efforts and results before the community in a manner that could hardly be duplicated otherwise.

Sol Seid, Supervisor, Dept. of Public Works, New Brunswick, N. J.:—Too many of us in the sewage field feel that our plant is away from everybody so why be concerned with anybody bothering us. We make a serious mistake in not letting the public know just what type of job we do.

In our community we have a very progressive mayor, a young man. He and I met with the superintendent of schools about eight years ago, at which time a program was instituted whereby the various members of the city government spoke for one hour before the classes on civic government—I think they call it "Problems of Democracy." It was amazing to me how little the senior students, who within a few years would be voters of the community, knew about their city government and its various functions. At the same time there was instituted a program whereby the students elected their own government, and they themselves selected the various appointive municipal department heads. There was a superintendent of the sewage plant and a superintendent of public works. These boys and girls did a splendid job. There are certainly more people in our community now that know about sewage treatment than there ever were before.

I would like to bear out what Mr. Sperry has said about speaking before various service clubs. We have made it a practice to appear before any service club when so requested. As a con-

sequence, our public has become acquainted with us. The important things in public relations are keeping your plant nice, inviting the public, and getting into the press. I agree with Mr. Sperry that you should write your own articles, because the reporter usually messes up what you want said.

The most important item, however, is getting out of one's shell. Remember that your job is as important as any other job in the municipal, or state, or federal government. Don't be afraid to say your piece. Once we do that, the public is going to know what we are doing and how important our job is.

Chairman Larson:—I can agree heartily with Mr. Sperry's statements about the attitude we should assume when called on the telephone. There is probably nothing more formidable than an irate housewife at the other end the line. It has always been my experience, however, that rather than to argue, if one just listens, sympathizes, admits there is a bad condition existing, and does all he can to correct it, pretty soon her steam runs down. In other words, a nice bedside manner is important. I can't resist the temptation to remind all operators that despite the rather unsavory function we are called upon to perform, we do have connections with the best families in town.

Richard M. Babcock, Public Health Engineer, State Department of Health, Lincoln, Nebr.:—One thing that should be mentioned in the matter of public relations is the beautification of the plant grounds. Regardless of whether it is large or small, the attitude of the public is directly reflected in the visible condition of the plant. To me that is very important.

Chairman Larson:—I agree with that. I am sure the public is more concerned with how a thing looks than with how it works. And if a thing looks well, it isn't absolutely true, but it is a corollary that it will work well.

H. T. Rudgal, Superintendent, Water and Sewage Departments, Kenosha, Wis.:—Unconsciously the public attaches a little stigma to anything connected with sewage. It is an absolute "must" for every superintendent of a sewage treatment plant, especially in the smaller cities and the country towns, to put on a good public relations campaign of some sort. Unless it is done, there will always be that stigma, although there is no reason why there should be. Actually, how people react when you say you are superintendent of sewage is a gage of the effectiveness of your public relations program.

Effect of Detergents on Sewage Treatment Plants

Walter E. Merrill, Associate Sanitary Engineer, State Department of Public Health, Boston, Mass.:—Two years ago, at Detroit, Dr. Rudolfs gave a paper * that is worth-while looking up for anyone interested in the effect of detergents on sewage treatment plants. With that "back-handed" introduction I am going to read a short paper on "The Effect of Two Detergents on Sedimentation," by Joseph A. McCarthy, chief of laboratory at the Lawrence (Mass.) Experiment Station. Mr. McCarthy was scheduled to be on this panel, but could not get away for the meeting. He writes as follows:

During the past year, various studies have been made from time to time at the Lawrence (Mass.) Experiment Station on the effect of commercial detergents on the sedimentation of domestic sewage. Part of the work has been laboratory experiments under controlled conditions; the other work has been done at a small state institution, where the daily volume of domestic sewage is quite uniform but the volume of the waste from the laundry varies considerably from day to day. The domestic sewage includes waste from dishwash-

* Rudolfs, W., Manganelli, R., and Gellman, I., "Effect of Certain Detergents on Sewage Treatment." *Sewage Works Jour.*, **21**, 4, 605 (July, 1949).

TABLE I.—Sedimentation of Institution Waste

Laundry Waste (%)	Suspended Solids						
	Raw Waste (p.p.m.)	Imhoff Cones			Settling Tank		
		Settled (p.p.m.)	Removed (p.p.m.)	Removed (%)	Settled (p.p.m.)	Removed (p.p.m.)	Removed (%)
8	82	63	19	23	113	0	0
15	158	85	73	46	94	64	40
19	114	80	34	30	95	29	25
26	140	96	44	31	106	34	24

ing with a very small amount of synthetic detergents; in the laundry processes, varying amounts of soap are used according to the materials being washed, but a fairly constant amount of Hexolate, a commercial detergent equivalent to about 500 p.p.m. is used in all washes.

The mixed sewage and wastes are discharged to a settling tank with two settling chambers, which fill alternately and afford an average settling time of about 2 hr. during maximum flow. There is considerable leakage from one chamber to the other. Both chambers showed small amounts of floating sludge.

Composite samples were collected for at least 4 hr. on four consecutive days of the mixed sewage and waste applied to the tank and of the tank effluent. The proportion of laundry waste varied from 8 per cent of the total flow on the first day to 26 per cent on the fourth day.

In addition to the samples taken from the tank itself, carefully mixed samples of the influent composite were settled in Imhoff cones for 2 hr. As shown in Table I, the amount of suspended solids removed did not vary with the increase in the amount of laundry waste present. In fact, in both the tank samples and in the cones the poorest settling was shown with the lowest amount of laundry waste. B.O.D. determinations showed approximately the same reduction on all four days. Although the poor operating condition of the settling tank reduces somewhat the value of these observations, it does not appear that concentrations of this detergent up to about 100 p.p.m. had any significant effect on the settling characteristics of the sewage.

In all of the laboratory experiments (Table II) Dreft was used as a typical household detergent. This material is reported to contain about 30 per cent keryl benzene sodium sulfonate. Several lots of domestic sewage were treated with increasing amounts of Dreft, carefully mixed in 1-gal. bottles. These were then settled for periods ranging from 0.5 to 2 hr., with determinations of suspended solids being made before and after settling.

In one of these experiments (run No. 1), the amount of solids removed by sedimentation in 1 hr. showed a sharp drop in sewage containing 25 or more p.p.m. of this detergent. In another case (run No. 2), a slight reduction in material settled was shown. In all other runs, the removal of solids seems to be affected more by the probable error of determinations than by the amount of detergent present.

The general conclusion from these experiments seems to be that with amounts up to 100 p.p.m. of the two detergents studied, there is normally little if any effect on the sedimentation of domestic sewage.

Chairman Larson:—The amount of work that has been done on this subject is rather meager. It is gratifying to know that detergents apparently are not affecting the efficiency of treatment units, but they are certainly a nuisance,

as we in the Middle West are finding out.

Synthetic detergents are here to stay, although their use is just in its infancy. In fact, if we can believe some of the radio announcers, we wonder how we have lived so long without these products.

TABLE II.—Laboratory Sedimentation Experiments with Dreft

Dreft Conc. (p.p.m.)	Settl. Time (hr.)	Suspended Solids			
		Raw Sewage (p.p.m.)	Settled Sewage (p.p.m.)	Removed	
				(p.p.m.)	(%)
(*a*) Run No. 1					
0	1	240	108	132	55
10		228	110	118	52
25		248	156	92	37
50		246	153	93	38
100		232	153	79	34
200		228	152	76	33
(*b*) Run No. 2					
0	1	386	222	164	43
10		352	235	117	33
25		376	232	144	38
50		384	236	148	39
100		377	225	152	40
(*c*) Run No. 3					
0	0.5	210	130	80	38
10		188	118	70	37
25		212	127	85	40
50		184	115	69	38
100		176	110	66	38
0	1	204	114	90	44
10		236	115	121	52
25		188	112	76	41
50		200	134	66	33
100		220	110	110	50
0	2	196	96	100	51
10		204	102	102	50
25		190	93	97	51
50		178	100	78	44
100		200	88	112	56
(*d*) Run No. 4					
0	2	325	141	184	57
100		288	128	160	56
(*e*) Run No. 5					
0	2	161	92	69	43
100		160	85	75	46

W. Rudolfs, Chairman, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.:—The statement made by Mr. Larson holds only for the type of detergent which Mr. McCarthy was using, anionic materials. Other types of detergents present an entirely different story. They produce a beneficial effect on solids removal.

The figures on removal by sedimentation in an Imhoff cone do not tell the whole story. You might have a difference of 1 per cent, and it is just that 1 per cent which is very finely divided material. As a rule, you will not expect great differences with any of the household detergents, except in other effects than sedimentation. A great increase in use of detergents can be expected, however. This year detergents are predicted to be about 40 per cent of all the soap used, whereas three years ago they represented 6 per cent of the total amount of soap used.

We have made a large number of studies on this subject pertaining to the effects on the bacteria, the effect on sludge, the effect on aeration, the effect on filters, and so forth. They are too lengthy to describe here. However, as a rule, we find that the least effect is found with the anionic detergents.

Chairman Larson:—Do I understand that we don't need to worry about detergents?

Dr. Rudolfs:—I wouldn't say that. The worries are more about the nuisance phase, although, if the quantities of detergents increase, they also are going to have certain effects on the biological communities. This is because a detergent interferes with absorption, penetration, etc., and masses of material moving in and out of the filter. An effect also can be expected on the purification with increased quantities, but the normal quantities expected from households, even if all the soap were replaced by detergents, will be

more a nuisance factor than a purification effect. As soon as you have industrial wastes or industries that use large quantities, then we have an entirely different story. Also, if municipal use of detergents for degreasing streets increases, then we will have still another problem.

Chairman Larson:— I think, generally speaking, those who have surface aerators are troubled more than those having air diffusion units, because of the thrashing of the surface film.

Richard F. Snyder, Sanitary Engineer, Massillon, Ohio:—Regarding the nuisance factor, the superintendent at one plant I know of has considerable difficulty. The plant is located on a side hill, and there is considerable head to dissipate between the trickling filters and the final settling tank. There are some aeration steps in the distribution chamber to dissipate that velocity head and to pick up as much oxygen as possible on the way. As a result at various times each day when the detergent comes down through there from local laundry wastes, the foam comes out of a distribution manhole that has a 4-ft. square ventilation grating opening on top. The froth covers quite an area, which has to be cleaned up. That is certainly a nuisance factor.

Dr. Rudolfs:—Defoaming agents, which for a small plant would cost probably 5¢ per day, are available to get rid of the foam.

Chairman Larson:—Are they successful?

Dr. Rudolfs:—Yes. I should mention at the same time that there is considerable evidence that when detergents are used in considerable quantities, the trickling filters deteriorate and do not work as effectively; the material accumulates, resulting in anaerobic conditions. That, of course, interferes with the purification process. There is considerable evidence of a great deal of build-up and further difficulties to be expected. However, these things can't be found by one test.

Chairman Larson:—How are the several defoaming materials characterized?

Dr. Rudolfs:—They are called antifoam agents.

From the Floor:—We have had that trouble in Texas. Some years back we licked it very easily with water sprays, using the effluent.

Gail P. Edwards, Professor of Sanitary Chemistry, New York University:—We have made some plant-scale tests on defoamers, which have been moderately successful. There are several factors to be considered in foaming in aeration tanks. In the first place, the farther the sewage goes through the aerator, the greater the foam becomes. For example, most of our tanks have four passes. There may be a little foam in the first pass, more foam in the second; it will build up in the third and fourth passes, and then, if you have a good wind which tends to blow it over in that same direction, it looks like a snowbank in July.

We have found that we get more foam early in the morning. That is, after a long aeration period during the night, we get more foam than late in the afternoon or in the evening.

We have tried quite a number of these defoamers. One trouble is that the defoamer loses its effectiveness as it goes through the aerator. If a reasonable amount of a cheap defoamer could be added to the return sludge, and carried through the plant, it would be fine. It may be that, after about an hour in the tank, the defoamer is oxidized or adsorbed on the sludge. At any rate, its effectiveness disappears. This applies to the first product tried.

We tried another one on a small scale. We are going to try it on a little larger scale to see if it actually does work, but it did appear to stand up for a longer period. We are not certain that it will go through the plant, but it did look a little better.

As Dr. Rudolfs said, there are a great many of these defoamers. Some are made from by-products of the animal food industry, others from petro-

leum and still others are silicones. Certain types of silicones and emulsified silicones were ineffective in our particular case.

The fact that less foam forms with raw sewage makes a couple of things possible. Someone mentioned spraying of settled sewage. Spraying does help. We have used it quite effectively but spraying creates another hazard, freezing, and, as a result, slippery walks. We have had to change several sampling points for this reason.

We have another advantage, in that our plants are all equipped for step aeration. That permits addition of sewage at various places along the course of flow through the aeration tanks, a procedure found to be quite effective. Wherever the settled sewage is added, the foam disappears.

We wrote letters to a number of plants and it seemed to be the consensus that the effluent and the activated sludge were certainly no worse at the time the foaming occurred than they were at other times. It did not seem to have any injurious effect on the activated sludge process.

Getting back to the effect of the defoamers for a minute, we were very much interested and rather concerned at first as to what would be the build-up effect of these defoamers. Would they become attached to the sludge and return? Might they have a beneficial effect so that we could decrease the amount of defoamer afterwards? Or would they have an injurious effect? Would they coat the sludge so that it was less of an absorbing agent, or would they have an injurious effect on the organism? To the best of our knowledge, the defoamers we tried did not have any harmful effect and they didn't have any carryover. They seemed to lose their effectiveness. They had no effect on settling and no effect on purification.

Of course, these are all short-time experiments and they certainly are far from conclusive. They are just observations we have been able to make on very limited experimentation.

From the Floor:—We find that sunlight has the effect of breaking the bubble. Also, if you are troubled with freezing, I believe an air jet or a broad jet located just below the lip of the tank might have the desired effect of breaking it up without the freezing problem.

Dr. Edwards:—The more you aerate sewage, the more foam you are going to get. But it may be that air applied at the top may knock down that foam.

From the Floor:—Is it correct, Dr. Edwards, that you found a direct relationship between the solids content and the degree of foaming?

Dr. Edwards:—The solids concentration in the aerators is a factor in foaming. In 1941, before the synthetic detergent problem became important, we could cause foaming if the aeration solids were in the vicinity of 800–1,000 p.p.m. Although this is too low, ordinarily, for activated sludge, we would, on occasion, get into that range.

Actually, we have no definite proof that synthetic detergents are causing foaming. We believe that they are responsible but we can't say positively. With four batteries in one plant, one may foam and the others may not. Each receives exactly the same sewage but other conditions in each of the batteries may be different. If the foaming is caused only by synthetic detergents, I see no reason why they shouldn't all foam. Foaming is probably caused by a combination of synthetic detergents and other factors or conditions.

Chairman Larson:—We have no more foaming on Monday afternoon, after washday, than we do at other times of the week.

Dr. Edwards:—In some cities the Monday washday has really gone out. People rush their laundry to the laundromat on Friday night, or Saturday, or any other day of the week. The washday peak has been pretty well evened out.

I have also been informed—and I believe the information to be reliable—that relatively few laundries in New York City are using synthetic detergents. When this information was given to me a few months ago, the cost of soap was still considerably lower than that of synthetic detergents. When the big laundries switch to detergents we really shall have a problem.

Chairman Larson:—I understand that synthetic detergents are in quite general use in England and abroad. Perhaps some of our English members present have something to say on the subject.

Arthur Key, Senior Chemical Inspector, Ministry of Health, London, England:—In the United Kingdom, the situation seems to be similar to what it is here. People have not yet made up their minds whether synthetic detergents are going to be a source of great trouble or merely a nuisance as far as sewage works are concerned. We have one or two very exceptional cases in England where synthetic detergents may be present in abnormally great concentration due to effluents from wool scouring. Those processors normally use soap, and the quantity of grease in the sewage is so large that grease recovery is a practicable and economical proposition. The grease recovery is effected by acidification so as to crack the grease, and subsequent sludge pressing. Insofar as these manufacturers use synthetic detergents instead of soap the addition of acid may no longer crack the grease, and grease recovery and sewage treatment may be rendered much more difficult. In those particular areas, therefore, the sewage authorities are particularly worried about synthetic detergents.

In other areas, so far as I have been able to find out, it is largely the nuisance of foam which has caused comment. One works, for instance, became pretty well smothered with foam the day after a popular detergent was released in the district with a large advertising campaign—and the foam has been there ever since! No one could prove, of course, that the one was the cause of the other; but most people think it is. Whether our detergents have the same composition as yours I do not know.

One of the difficulties—and I think you also have the same difficulty—is that we do not always know what particular type of synthetic detergent is the basis of the various preparations that are marketed and sold. I am quite certain that the different types have different properties, not perhaps in relation to sedimentation, but certainly in relation to the biological stage of sewage treatment. In all investigations on that stage I think it is essential that we should not only know the trade name of the detergent we are investigating, but also its chemical constitution.

From the Floor:—During two years of operation, we had considerable foaming when our D.O. got higher. In other words, every time we got foaming we checked and found an increase in D.O. in the secondary aeration tank. Usually it would be worse in the morning after a quiescent night. So, the D.O. content may enter into consideration of causes during the foaming period.

Chairman Larson:—That is rather interesting. Dissolved oxygen might be correlated with the foaming, as well as the solids referred to by Dr. Edwards.

THE DAILY LOG

Marion, Indiana

By David P. Backmeyer, *Superintendent*

June 5—A phone call from the lady who lives adjacent to our pumping station property reminds us that we have been negligent in the maintenance of the yard at this site. Frequent rains have made it almost impossible to keep the lawn in presentable condition; now we will have to borrow a sickle bar cutter to remove the top 15 in. of growth before the regular mower can be used. "A stitch in time" would have saved us several man-hours. We are usually proud to show this attractive station site to any visitors who might be dubious about having a sewage pumping station in a residential area (see Figure 1).

June 11—A group of 22 ladies representing the local League of Women Voters organization spent a couple of hours at the treatment plant this afternoon. Their complimentary remarks about the appearance of the plant are passed on to our day shift plant operators, who deserve the credit for that extra touch of good housekeeping that makes the difference between ordinary maintenance and exceptional maintenance.

June 15—Our new tank truck for trucking liquid digested sludge to farm land was delivered today. This unit (Figure 2) is quite an improvement over the first unit (Figure 3) put in service three years ago. When loaded, this truck weighs 21,750 lb.; our driver is handling a $3,300 investment in sludge disposal equipment when he pulls out with this baby. We have had our share of development and growing pains with the former tank

FIGURE 1.—Well-maintained sewage pumping station in South Marion, Ind., is absolutely unobjectionable in residential area.

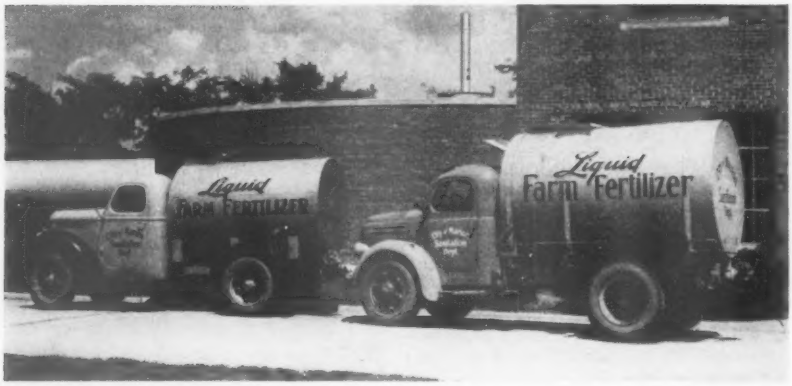

FIGURE 2.—"Late model" liquid sludge tank trucks of 1,000-gal. and 1,500-gal. capacity (left and right, respectively) show vast improvement over original pilot model.

trucks, some of the most severe of which were due to material shortages of the war period.

June 18—The renewable wearing shoe plates on our grit collector are ready for a half-sole job. Most of the wear is on the toe end of the shoe, and another year's service can be gotten by welding a strip of strap iron securely in place at this point.

June 19—An avoidable accident almost mars our otherwise successful aeration tube cleaning project (see THIS JOURNAL, **22**, 10, 1366; Oct., 1950). Operator Wally Sult attempted to defy one of Mother Nature's rather dependable laws by taking a flying leap from the top rung of the step ladder to the bottom of the drained aeration tank. He landed with a thud and splash in the 6-in. depth of septic activated sludge, and was indeed fortunate in receiving injuries of only a minor nature. After discarding his clothing (which had that peculiar odor known only to those who have had first-hand experience with same) and getting first aid treatment at the plant laboratory aid station, our "flyer" was back on the job, considerably wiser, not too much the worse for his harrowing experience.

FIGURE 3.—Forerunner of Marion's efficient sludge delivery fleet was this 960-gal. tank and pump built on plant dump truck.

June 27—Picked up former County Agricultural Agent at 3:30 this morning and departed for a fishing session at the treatment plant quarry lake. We were hoping the "big ones" would be hungry just after daybreak. At eight o'clock the only thing we had to show for our activities was a super-good appetite. We would just about make an even bet that there aren't any fish in the lake.

June 29—Part of our flow was given only primary treatment this morning. The activated plant is in a mess as a result of a shock load of 2,500 gal. of cheese whey dumped to the sewer five days ago. The sludge index has soared to 200. This incident calls for another visit with the manager of a local milk processing plant. His next sewage treatment service charge will contain an item covering the cost of operating an additional 75-hp. motor-driven blower needed to condition the activated plant. It certainly looked and smelled putrid after this stuff hit us.

July 6—Our new thermometer, which will indicate the temperature of the raw sewage, was installed in the main line entering the plant. Our operators will take 12 readings each day. Although the sewer invert is 22 ft. below the yard grade, a stainless steel cable of proper length affords an easy means of mounting the indicating dial at eye level for reading convenience.

July 8—Our gas storage cylinder was given its biannual cleaning and paint job. There are very few corroded spots to buff out, and the job doesn't take long after the cleaning and touch-up work is finished. We learned several years ago that it doesn't pay to cover any of the surface that shows evidence of pitting or rusting until a thorough cleaning and priming job is done.

July 10—We are hosts to a delegation of 25 visitors from South Bend, Ind. These men were principally interested in observing the prevalence of odor nuisance in the immediate vicinity of our activated sludge plant. The party spent several hours at the plant site, and then drove out to visit personally the neighbors living within one-half mile of the plant. The general reaction of the neighborhood was favorable. One exception, that stood out like a sore thumb, was the week-end period when our front yard lawn was wet down with waste activated sludge in anticipation of a shower of rain that seemed imminent. The rain came four days later, and was preceded by hot humid weather. We'll never gamble on another deal like that again!

July 16—Our three gas engines have been serviced and are ready for a 9-month run during the heavy load season immediately ahead. In checking the No. 3 75-hp. engine today, we note the fuel requirement is 7.47 B.t.u. per cu. ft. of air delivered at 7.75 p.s.i. line pressure. The capacity of the blower is 1,800 c.f.m.

July 21—Three of our men completed the short course school (operators) that was conducted each Wednesday by the State Board of Health and Purdue University. The final examination questions were very interesting and required considerable straight thinking in most cases. The teachers, as well as the pupils, certainly gained a lot from these sessions!

July 23—Operator found several bad spots in built-up roof of digester floating cover. Much to our surprise, the sheathing was rotted out in several places, and presented a difficult repair job. A complete examination of the steel beneath the wood decking shows a need for a cleaning and paint job. This work is scheduled for next February when weather conditions will permit, as summer temperatures run as high as 120° F. in the limited working space between the steel cover and the roof deck.

July 25—Our gas engine-driven raw sewage pump is dismantled to replace badly worn wearing rings. This is a horizontal low-head pump rated at 4,000 g.p.m. under 33 ft. total head. These rings had handled 4,893 m.g. of

raw sewage; a previous set had been in use for a 5,902-m.g. pumpage. It is important that replacement be made before wear on the impeller casting requires additional maintenance. Badly worn rings cause reduced pumping efficiencies, which may increase the power demand for pumping as much as 25 per cent.

July 31—Our entire stock of machine bolts and cap screws (a variety of convenient sizes kept on hand for general maintenance work) is taken to a local metal plating shop and zinc electroplated. The nominal cost of 5¢ per pound is good insurance against corrosion hazards.

August 4—Spent a couple hours this morning with our County Agricultural Agent inspecting a field of Sudan grass that had been dosed with liquid sewage sludge about three weeks ago. Colored photos were taken of one particular area where a strip about 2 ft. wide had been missed by the tank truck. The contrast was remarkable; the treated grass showed a gain of 300 per cent over the untreated area.

August 15—Drove to Somerset this morning at 7:00 A.M. This little village is located on the Mississinewa River, about 15 mi. downstream from Marion. A group of Boy Scouts is camping there enroute to Peru, Ind., by way of boat passage on the Mississinewa. (This is strictly a business trip, as it must be remembered that one of the duties of the S.T.P. manager is to know first-hand the condition of the receiving stream.) Nine boats completed the last leg of the journey. Excitement is intense on several occasions when largemouth bass are captured barehanded as they skip and jump into the boats. Several snapshots were taken of the catch, as we knew the folks back home would consider this episode another "fish" story. The writer was just as skeptical as the other listeners until one of these babies landed square in his lap. The river is apparently in satisfactory condition for thriving fish and plant life.

August 19—Our latest gadget, an oil leak detector, used on the gas engines to check excessive loss of oil at the main and crank bearings, was given a trial today. A sizeable spurt is noted at the front camshaft bearing. This could be the cause of the low oil pressure which has been plaguing our plant operators for some time.

August 28—The tomato canning season starts, and will run concurrently with the corn pack for several weeks. The combination of the two is more than our activated sludge plant can handle. This is the time of the year when we hope and pray that we'll get at least one shower each week. Rainwater dilution reduces the load and acts as a governor on our sludge index.

August 29—Our garbage grinder will need treatment for a severe case of halitosis! Today we ground a ton of spoiled onions, which were brought in by a local wholesale produce house. Another recent "hot grind" consisted of about eight tons of red peppers that were not suitable for sale. The ground material is pumped from the garbage well and added directly to the plant digesters. Wouldn't be surprised if the B.t.u. content of the gas showed an increase following the addition of the red peppers!

August 31—We trucked a 1,500-gal. tank load of digested sewage sludge to Terre Haute today in response to a request from Don Bloodgood. The round trip involved a 280-mi. drive. Prof. Bloodgood is using the sludge in his experimental work at the Terre Haute Paper Co. Our location was chosen as the source of supply because of the convenience features involved in the unloading of the truck at the paper mill digester site. This is really spreading it a long way from home!

TAKING THE SPRAY OUT OF SLUDGE PUMPS

By Russell Grinnell
Superintendent, Sewage Treatment Plant, Birmingham, Mich.

One evening some time ago, the writer went to a party given by some of the staff of the Detroit, Mich., sewage treatment plant. All those invited worked in sewage plants in and around Detroit. We had a good time.

The instigators had taken over a night spot for the evening. There was a nice dinner and some professional entertainment. After that the committee put on some stunts. I remember one in particular—the initiation into the "Order of the Smear." The master of ceremonies explained that in order to belong to the Order it was necessary that at some time or other you must have been sprayed with sludge by a sludge pump. It happened that I was eligible. I had been showered with sludge by a sludge pump, but not just once.

"Keep your seat," I said to myself. "Don't get up there and make a fool of yourself. No one but you is stupid enough to let that happen." But I was surprised—almost half of the company stood up and went forward for the initiation. They ended up by giving us each a badge. I still have mine around here some place.

Being "smeared" with sludge by a sludge pump is not a pleasant experience. It's messy. After the ordeal, until the victim can take a bath and get into fresh clothes, there is no sort of company in which he finds himself welcome. Also, unless the accident happens on a Saturday, it means an extra bath and there's an old saying that too many baths weaken one. Furthermore, the women folk take a dim view of washing those clothes.

The day after the party I went down and took a good look at the sludge pumps in my plant. "All those people," I thought, "who have sludge pumps just like these, have been sprayed. And what about all the times I have been squirted by these very pumps?"

Cause of the Trouble

Usually, when you have trouble with a sludge pump it is because there is something under one of the valves and holding it open. It is up to you to open the pump and get it out. You close the valves on either side. That keeps the sludge from coming at you from the lines; but all is still not well. The pump is still full of sludge and it is under pressure. The air chamber causes that.

It is a bit like being confronted by an armed man. Having an armed man around the place, bent on mischief, is not a comfortable situation. It makes it hard to relax. It is a lot nicer if you can safely disarm him, or, in this case, "disarm" the plugged sludge pump. It is necessary to remove the stick that is holding one of the valves open. Can it be done safely? If only we could relieve the pressure behind the sludge it couldn't fly at us and we would be safe. Apparently, however, the way the pumps were installed at Birmingham—and seemingly in a lot of other plants—it couldn't be done.

Simple Solution

Nevertheless, study of the matter revealed that installing a few valves and fittings would do the trick. Sludge pumps are simple pieces of machinery. They seldom give trouble; when they do it is easy to get them going again. Everything is in the open, easy to get at. Now that they have been disarmed I suspect they are, possibly, our favorite machines.

All the valves and fittings used are standard parts. Figures 1, 2, and 3 show where and how they were put on. There are three places where the pressure must be relieved—the suction

FIGURE 1.—Pressure relief on suction side of sludge pump consists of 2-in. fittings tapped into blind flange.

side, the air chamber, and the discharge side.

Figure 1 shows the relief valve on the suction side. The blind flange was replaced by one threaded for a 2-in. pipe and the 2-in. valve was installed. Fittings smaller than 2 in. would be liable to clog and probably should not be used.

Figure 2 shows the relief valve for the air chamber. As clogging is not a problem here, ½-in. fittings were used. The 30-lb. suction—60-lb. pressure gage is not a part of this system, but is very useful. It shows that the pump is pumping properly, or if not, where the trouble is.

The relief valve for the discharge side is shown in Figure 3. There was a 1-in. sampling cock here; it was always plugged. The 8-in. tee was removed and drilled and tapped for a 2-in. pipe, to act not only as a relief valve, but also as a usable sampling point.

FIGURE 2.—Air chamber relief is made up of ½-in. fittings.

Figure 4 shows the gaskets for the ball-valve cover. The type supplied by the pump manufacturer are of 1/16-in. rubber cut as shown at left. They aren't much good. No matter how carefully they are installed and tightened down, they can open up and spray an unwary passerby with a squirt of sludge. Those we have designed and installed to replace them are of ⅛-in.

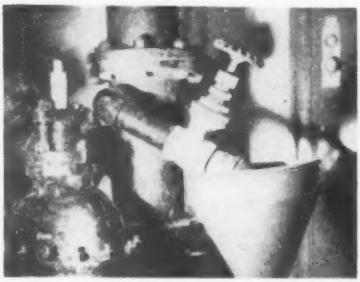

FIGURE 3.—Discharge relief of 2-in. fittings also provides usable sampling point.

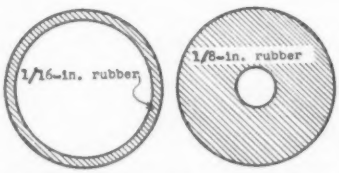

FIGURE 4.—Thicker and wider ball-valve cover gasket (right) eliminates rupturing trouble caused by thin narrow gasket (left) supplied by manufacturer.

rubber cut as shown at right. They are much safer, as it is almost impossible for them to pull away from the seat.

After all this disarming is done, you can still be smeared, but not if you are careful. There are usually lots of valves around sludge pumps. You think one is open; it is closed, or vice versa. That is bad. Every last valve must be carefully checked, as even this system isn't quite fool-proof.

SEWER SERVICE CONNECTION POLICIES *

By Stanford E. Harris

Superintendent, Water and Sewerage Division, Winston-Salem, N. C.

With many other problems confronting the municipal engineer, the establishment of sound, workable policies concerning sewer service connections is frequently overlooked. As long as sewer connections function properly they are unseen and unthought of. Let them fail, however, and there is an immediate reminder that they are one of the basic conveniences of urban life. It is readily recognized that due to the difference in size of municipalities there must be variety in sewer service connection policies. However, there should be recognition of the facts that: (1) The disposal problem begins at the domestic or industrial service connection and (2) this connection is the only part with which the average citizen becomes acquainted and the entire system is usually appraised by its dependability.

Sewer service connections are installed either by licensed plumbing contractors, employed by the party who desires the connection made, or by municipal forces. The first policy has the advantage of saving the municipality the expense of equipping and maintaining a crew to do this work and relieves the municipality of any liability should trouble develop on any part of the connection subsequent to its installation. There are also numerous disadvantages to this policy, but they are not discussed herein. In the majority of cases this policy is employed in only the smaller municipalities. The second policy—having installations made by municipal forces—is highly desirable and is recommended where practicable. It is believed that in any municipality where municipal forces install water service connections, this policy is practicable.

The following policies are suggested for municipalities where sewer service connections are installed by city forces.

Application for Sewer Connection

Any person or firm desiring a sewer service connection shall purchase same from the municipality upon payment of a charge equal to the estimated cost of all labor and materials required to complete the installation plus 15 per cent. This cost will include removing and replacing pavement when necessary. The applicant will give the name and address of the owner, the name of the building contractor, and the location where the service is desired.

Design

The service connection shall have a minimum size of 4 in. or 6 in. The pipe will be made of cast iron, asbestos cement, or vitrified clay. Jointing material will be of such composition as to prevent tree root penetration through the joint. The service connection will be extended to a point behind the theoretical curb line of the street, at which point a suitable cleanout will be installed. The minimum depth of bury at the curb line will be 3 ft. where practical. Whenever the difference in elevation between the sewer main in the street and the service connection at the curb line is less than 4 ft. a suitable back-pressure valve shall be installed just beyond the cleanout. The diameter of all sewer service connections shall be determined by the municipality.

Maintenance

The municipality shall maintain sewer service connections at no cost to the property owner, from the main to

* Presented at 1950 Annual Meeting, North Carolina Sewage and Industrial Wastes Assn.; Durham, N. C.; Nov. 13–15, 1950.

the cleanout installed at the curb line. From this point into the building maintenance of the connection shall be the responsibility of the property owner.

General Policies

In no instance shall two or more buildings be allowed to be connected to one common sewer connection.

Whenever any large installation (such as large commercial laundries, hospitals, multiple housing units, school buildings, etc.) desires a service connection, this connection shall be made to the sewer main by construction of a suitable manhole at the main. In this instance, the cleanout at the curb line will be omitted. Maintenance of the connection shall be the municipality's responsibility to the curb line.

Storm water from roof drains, air conditioning waste water, waste water from automotive wash pits, and other similar wastes will not be allowed to be connected to the sanitary sewer service connection.

Whenever a sewer service connection is desired for a location not abutting a city street, the permit or application will not be approved until the applicant shows a recorded grant of easement for all property to be crossed by the connection.

Conclusion

Sewer service connection policies should be consistent with water service connection policies insofar as is possible. This applies to both construction and maintenance policies.

TIPS AND QUIPS

Sewer Maintenance Schedules

A complete index system listing each section of a sewer system, together with pertinent information pertaining to that section, will more than pay for the time and energy expended in preparing it. Among the many advantages of such a record is a definite check on maintenance work necessary in the various locations, particularly with regard to stoppages from debris and roots. From the record of past requirements, inspection and maintenance schedules can be set up to remedy minor or potential troubles before they become Sunday, holiday, or dead-of-night emergencies.

Among the data that should be listed are:

1. Location of sewer section, by complete description.
2. Location of manholes along the section, by complete descriptions.
3. Size, type, depth, grade, and year of installation of section.
4. Number and locations of entering services or junctions with other lines.
5. Any previous unusual maintenance conditions, including sand infiltration, catch basin debris (in combined systems), root stoppages, etc., and notes as to the locations at which they occurred.
6. Each inspection made, with the condition found, the date, and the inspector's name or initials.
7. Maintenance work performed, including type, results, descriptive remarks of unusual conditions, date, and foreman's name or initials.

A file card index will make it easier to locate the entry for each section as inspected or worked on. In addition, the worst trouble spots can be separated, by degree, to aid in establishing a comprehensive routine inspection schedule for future use.

No False Alarm

A recent issue of *The Digester* (Division of Sanitary Engineering, Illinois Department of Public Health) contains a reminder of the ever-pres-

ent need for caution around a sewage treatment plant. In this case, one of the less alert operating help at an Illinois plant recently tossed a match into the Imhoff tanks. It not only set the gas aflame, but also started the grease and oils to burning. Before it was extinguished the fire ate up boardwalks and created quite a bit of excitement.

Cooperative Venture

All informed operators are aware of the hazards involved in an enclosed underground grit chamber such as the one at the Fort Wayne, Ind., sewage treatment plant. Usually the remedy is to educate all personnel as to the dangers involved and the precautions to be taken, then hope that any gasoline, oil, or other dangerous materials coming down to that point will pass on through the plant without causing trouble.

However, Superintendent Paul Brunner has worked out an additional precaution he feels is worth-while. Explaining the matter, he says:

"We have a very congenial working arrangement with the Fire Department. They call us whenever they know that inflammable material has gotten into the sewers; occasionally it has been possible to divert such material to the river before it gets to the plant. Notices are put in the local newspapers every so often advising residents and industries to notify the Fire Department if materials of this class do get into the sewer system, either accidentally or otherwise. The Fire Department then alerts the Sewer Department and the sewage treatment plant to be on the lookout and put prearranged safety measures into effect."

This local "good neighbor" policy might well be worked out in other communities to good advantage!

Fence Painting

Fences requiring painting, whether new or over an old coat of paint, should be wire brushed. If the fence is of the wire-mesh type and badly corroded, the loose paint and corrosion products can be removed by beating the mesh with a flat metal strip.

Will You Be There?

A recent issue of *Water and Sanitary Engineer* (British) contains an interesting comment on the Federation's 1950 Annual Meeting at Washington, D. C., as follows:

"A correspondent in one of the English Sunday newspapers reported that during the course of the Conference the Hotel Statler was filled with 'jolly' men and their well-dressed wives, and rather implied that this was a change from the usual cross-section of harassed business men normally encountered there."

All of which just goes to show that the Federation meeting is a good place to solve your problems and lose your worries! Why not begin planning now to attend the 1951 meeting at St. Paul, October, 8–11?

OPENING FOR CHIEF OPERATOR AT TACOMA, WASH.

A competitive examination has been announced on a non-residential basis for the position of Chief Sewage Plant Operator at the new Tacoma, Wash., sewage treatment plant. Further information and application blanks may be obtained by writing the Civil Service Office, Room 100, Tacoma 2, Wash.

Editorial

POLLUTION CONTROL AND THE NATIONAL EMERGENCY

An editorial in the March 22, 1951, issue of *Engineering News-Record* suggests that pollution control authorities should immediately reconsider all outstanding abatement orders in the light of the present national emergency, and issue new orders only "under the most convincing showing that the work cannot wait until the present peak of construction is past." It is hoped that our state and interstate anti-pollution agencies will not act hastily in accepting this advice, which is not blessed with the good judgment usually manifested by ENR writers.

In effect, the ENR proposal would nullify most of the hard-won progress that has been made in stream sanitation since 1946. It would sacrifice the momentum of a $300,000,000 per year construction rate in facilities that are sorely needed. Public support of clean stream campaigns, now at an all-time peak, would be allowed to lose its impetus. These gains should not be so casually abandoned.

At this time a substantial mobilization-for-defense program is being superimposed on a high-pressure civilian economy. We are told that this move is essential to insure world peace. There is much mention of "transition" and of "temporary dislocation," but there has as yet been no hint that we are headed into a total war economy such as we experienced in 1941–46. The U. S. Department of Commerce tells us that 45 per cent of our national output was devoted to defense at the peak of World War II (in 1944), as compared to an estimated 18 per cent that will be going to military purposes by the end of 1951. The present international situation is so obscure that any further attempt at analysis would be meaningless.

To date the federal authorities have seen fit to curtail only certain recreational, entertainment, and commercial activities in the interest of the defense program. There is as yet no indication from Washington that further retrenchment in civilian functions is necessary. There is, therefore, no more justification for the suspension of water pollution abatement campaigns at this time than there would be for similar action in the case of highways, flood control, land reclamation, soil erosion prevention, and other resource conservation measures.

Formal abatement orders are not issued by an authority unless serious pollution conditions exist. They are notices that the law is being violated, and they are issued only when the facts at hand will withstand legal attack. In most cases the polluters have had ample opportunity to act voluntarily, and have failed to do so in reasonable time. Many of them have begged out of their responsibilities on various excuses since the Great Depression. These violators will welcome the ENR policy recommendation as basis for a further reprieve.

The ENR admonition would be appropriate if another war was known to be inevitable—and then it would be unnecessary. We must rely on our national leadership to inform us if and when the importance of stream sanitation is transcended by an emergency situation. In the meantime, high prices, conscienceless labor practices, and problems of materials procurement will serve adequately to curb any tendency toward overzealousness on the part of pollution control authorities.

W. H. W.

Reviews and Abstracts*

Proceedings of the Fifth Industrial Waste Conference. *Eng. Bull.*, **34**, No. 4 (Extension Series No. 72), Purdue Univ. (July, 1950).

The United States Public Health Service Program in Industrial Waste Research. By V. G. MacKenzie. Pp. 7-14.

The industrial waste research program of the U. S. Public Health Service as being carried out mainly under the provisions of Public Law 845, the Water Pollution Act, enacted June 30, 1948, is reviewed.

There are three principal ways by which the Service supports and fosters industrial wastes research: (1) By grants to organizations or individuals for fundamental research through the National Institutes of Health; (2) by grants to states or interstate agencies for industrial wastes studies; and (3) by direct engagement in research and field investigations of industrial wastes problems.

The research grants program of the National Institutes of Health, makes grants in aid for such research projects as are recommended by the National Advisory Health Council. By established policy these projects are limited to those of a fundamental basic research character. Up to July, 1950, grants totaling $136,665 had been made.

For the fiscal year beginning July 1, 1949, Congress appropriated $1,000,000 for grants to states and interstate agencies for industrial wastes studies, allocated as follows: $850,000 to states on a formula basis. $60,000 to interstate agencies, and $90,000 to state and interstate agencies for special industrial wastes studies of regional or national significance.

The initial appropriation to the Public Health Service under the Water Pollution Act for direct operations was $445,000. This fund is permitting research and field investigations pertinent to water pollution problems, of which a major portion comprises industrial wastes studies. Participation of industry in the over-all water pollution control program is expected and is being realized by cooperation with regulatory agencies, by industrial group activities, and by individual industries. Of significance is the representation of industry on the Water Pollution Advisory Board, established to review and make recommendations on the water pollution control program and policies of the Public Health Service.

Public Health Service activities in connection with the water pollution control program are carried on through the Division of Water Pollution Control, Washington, D. C., ten river basin offices in various parts of the United States, and the Environmental Health Center at Cincinnati, Ohio.

The Ohio Valley Water Sanitation Compact Commission Looks Ahead. By J. L. Quinn. Pp. 15-21.

Briefly citing the history of the development of the Ohio River Valley Water Sanitation Compact, the author sets forth the magnitude of the pollution abatement problem, relates the necessity for uniform policy, and describes the proposed approach of the Ohio River Valley Water Sanitation Commission.

The states signatory to the compact are Indiana, West Virginia, Ohio, New York, Illinois, Kentucky, Pennsylvania, and Virginia. The basin area involved represents about 7 per cent of the total area of the United States and supports a total population of almost 19,000,000, approximately one-half of which is urban. Furthermore, much of the area is highly industrialized. There are some 1,680 communities served by sewers, thus presenting problems of sewage disposal. The industrial waste load, a more complex problem, originates from an estimated 1,600 significant sources.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

Regulatory agencies within the respective states have been and are active in attaining desired ends of water pollution abatement and control, but there is need for combined effort and for uniformity of policy, supervision and promotion of which are primary functions of the Commission. The proposed approach involves a public relations program for molding public opinion. Fundamentally, the Commission proposes to "sell" water pollution control, technical guidance serving as an important tool.

Industry and Pollution Abatement in the Ohio River Valley. By Edward J. Cleary. Pp. 22-28.

The author ably uses a specific occurrence to illustrate the relation of the Ohio River Valley Water Sanitation Compact Commission to the regulatory authorities of states signatory to the compact, to review the function of the Commission in abatement and control of water pollution in the Ohio River Basin, and to point out and emphasize the benefits of a sound and equitable policy in this respect to industry. The instance cited was one: In which the proposal of industrial wastes disposal from an anticipated new project of a nationally known chemical company, X, would produce a substantial increase in hardness to the Ohio River, thus concerning more than one state; in which the state regulatory authority's refusal to sanction the operation of a plant of this kind, unless satisfactory provision was made for waste disposal facilities eliminating the potential pollution, received support of the Commission through unanimous agreement of the sanitary engineers of the signatory states; in which company X accepted the decision of the state authority; but in which industry-promotion representatives publicly criticised the action as tending to halt industrial expansion. In narrative fashion the author describes a meeting of the Commission with a delegation of the industry-promotion group in which is offered an opportunity to clarify the objectives and operations of the commission.

The National Wildlife Federation—Its Aims and Objectives. By Carl D. Shoemaker. Pp. 29-39.

Introductory to the subject the author relates historic facts pertinent to developments in the wildlife movement in this country for the preservation, distribution, introduction, and restoration of game and other wild birds.

The objectives of the Federation in organizing were, and in functioning are:

1. To organize all agencies, societies, clubs, and individuals interested in the restoration and conservation of wildlife into a permanent, unified agency for the purpose of securing adequate public recognition of the needs and values of wildlife resources.
2. To develop a comprehensive program for the advancement, restoration, and conservation of wildlife.
3. To present to the public such pertinent facts, discoveries, and information as may contribute to the solution of the problems involved in the restoration and conservation of wildlife.
4. To cooperate with other general wildlife federations in other countries on this continent.

In the furtherance of these objectives, the Federation is empowered to take such steps, engage in such activities, and cooperate with the national and state governments and such other agencies as may be helpful and necessary to these aims.

Bruce M. McDill

Treatment and Disposal of Cyanide-Bearing Wastes. By John E. Tarman and Max U. Priester. Pp. 40-52.

Treatment requirements, manufacturing operations, methods of waste disposal, and treatment results, including analyses, are concisely and clearly given for several industries producing wastes with different characteristics.

Plant A cleans and plates small metal parts. Cleaning wastes are treated with acid to remove oils and then combinedwith plating wastes. Batch treatment with calcium hypochlorite is followed by acid treatment and settling. Plant B cleans and plates a different type metal part. Cyanide wastes are collected separately and batch treated with caustic soda and gaseous chlorine. After settling, the supernatant is decanted to the sewer and the sludge is discharged to drying beds.

Plant C does alkaline and acid cleaning, surface preparation, and enameling. Cyanide wastes are collected separately and batch treated with caustic and gaseous chlorine. They are then mixed with other

wastes, coagulated with alum and lime, and the solids removed. At Plant D clean, hot water discharged through old lagoons to effect cooling, leeched ferrocyanide from sludge in the lagoon. In the presence of sunlight ferrocyanides in the stream were converted to toxic cyanide. Installation of a cooling tower and changes in handling other wastes going to the lagoons solved the problem.

In treating cyanide wastes, pH was maintained at 8.0 to 8.5 and OTA chlorine residuals at 1 to 2 p. p. m. Concentrations of cyanide as high as 200 p. p. m. were reduced to zero by using approximate chlorine dosages in the ratio of 10 parts chlorine for each part cyanide.

Disposal of Waste Gases. By Marcus Sittenfield. Pp. 53-62.

Gases are divided into several classes and their characteristics and removal discussed on the basis of size and chemical or organic character. The following units or methods of removal are recommended: for large airborne particles, settling chambers, cyclonic separators, and water scrubbers; for small airborne particles, electrostatic precipitators, ultrasonic agglomeration, and cyclonic or Venturi-type water scrubbers; and for molecular materials, units for physical or chemical absorption, solution, or combustion. A discussion of each process is included.

Some specific problems and their solutions are described, such as the disposal and reclamation of metallic fumes and sulfurous gases from smelters through the use of bag filters, settling chambers, water scrubbers, and chemical extraction towers; the use of filters and cyclonic separators for removing dusts resulting from grinding operations; and various types of absorption towers or scrubbing for removing or recovering chemicals as hydrochloric acid, hydrofluoric acid, hydrogen sulfide, mercaptans, and organic sulfides.

A section is also included on the need for engineering design and economics of recovery.

Treatment for Disposal of Spent and Contaminated Soluble-Oil Mixtures. By D. J. Walker. Pp. 63-67.

This describes the process and results of two waste-oil treatment plants, each consisting of facilities for breaking emulsions and separating oils and sludge by means of acid and caustic treatment followed by clari-flow sedimentation. Wastes are varied and contaminated, having an oil content from 2,000 to 4,000 p. p. m. This oil is reduced with the aid of only 4 to 9 lb. of chemicals per 1,000 gal. of waste to less than 20 p. p. m.

Uses for Yeasts. By Elsie Singruen. Pp. 68-78.

The composition and properties of yeasts are briefly presented and uses for surplus and other yeasts are given. There is a good discussion on the production, nutritional components, and uses of brewers yeast with respect to animal and human consumption, and general information on the use of yeast for extracts, pharmaceuticals, and research purposes.

Strength of Wastes from Frozen Food Processing. By James A. Drake and Fred K. Bieri. Pp. 79-109.

A lagoon designed for a cannery was studied in relation to its use for wastes resulting from the preparation of frozen foods. Daily analyses and flow measurements were made and tabulated for pea, corn, lima bean, and carrot processing wastes. Results show, in general, a greater water usage and B. O. D. production per equivalent unit than for a cannery, averaging 60, 69, 85, and 55 gal., and 0.29, 1.11, 0.38, and 0.56 lb. of B. O. D. per equivalent case of peas, corn, beans, and carrots, respectively. In addition to the usual analyses, a chemical oxygen consumed determination was made and its correlation with B. O. D. graphically presented, with the view of possibly using this shorter test as a method of control.

The lagoons were overloaded and even though in the case of peas sufficient nitrate was added to supply 48 per cent of the oxygen required to satisfy the five-day B. O. D., objectionable odors occurred. For other wastes it was also determined that greater than the usual nitrate dosage was required. Analytical and other data were obtained almost daily for the lagoons and complete tables are included. The mass of data included for raw wastes, nitrate dosage, and lagoon characteristics should be valuable in comparing or studying disposal of similar wastes.

Recent Developments in Chlorination in the Beet Sugar Industry. By E. A. Pearson and C. N. Sawyer. Pp. 110-123.

Of the five sources of wastes resulting from the processing of sugar beets, the flume water and the process waste water were selected for treatment with chlorine, with re-use of these wastes as an objective. Flow diagrams and pictures show the arrangement used for each waste. Application of chlorine to the flume water at the beet washer reduced biological and slime growths and the objectionable odors usually prevalent in a closed system. Treatment of process water with chlorine and lime followed by coagulation and sedimentation made it possible to return that water to the battery supply tank. Treatment of process waters reduced the B. O. D. by 31 per cent and resulted in an increased sugar yield. The principles affecting operations and the improvements in the extracting process are discussed.

Wm. A. Hasfurther

The Waste Disposal Program of the Sinclair Refining Company, East Chicago, Indiana. By James A. Fowler. Pp. 124-129.

Improvements in the waste disposal system at the Sinclair Refining Company plant at East Chicago, Ind., were made as the result of a 1943 suit before the U. S. Supreme Court.

The basic features of the Sinclair waste disposal program include separation of sanitary sewage from process waste and its discharge into the East Chicago city sewer, reduction in the volume of refinery wastes, construction of an A. P. I. separator of adequate size, and treatment of heavily polluted wastes at their process source.

Cooling towers with a total capacity of 95,500 g. p. m. were installed, with provision for additional units as plant expansion required. A new A. P. I. separator with a capacity of 7,500 g. p. m. was constructed; the existing separator was revamped and placed in series with the new separator.

Treatment of heavily polluted wastes at their source was accomplished by remodeling the light oil treating plant and by installation of solvent extraction units for treating lubricating oils. In the former installation, towers of rock and salt were built to remove traces of treating agents remaining in the oil, thus eliminating the necessity for washing the treated oil with water and eliminating 1,800 g. p. m. of sulfide and phenol wastes. The solvent extraction units eliminate acid treating and prevent the formation of stable oil-in-water emulsions, which cannot be removed in gravity-type separators.

In addition, waste caustic is treated by contact with air and steam in a packed tower, converting 95 per cent of the sulfides in the waste caustic to thiosulfates.

With a present crude oil capacity of 85,000 bbl. per day, operating changes have reduced the volume of wastes to 5,000 g. p. m. as compared with 34,000 g. p. m. when the capacity was only 55,000 bbl. per day. Part of the saving has resulted from a campaign within the plant to conserve water in the interests of reducing the amount of plant effluent.

No data are furnished to indicate the reduction in over-all pollution of the dead-end branch of the Indiana Harbor and Ship Canal, to which the plant effluent discharges.

Treatment of Dairy Waste by Aeration. I. Methods of Study. By Nandor Porges and Sam R. Hoover. Pp. 130-136.

This is a condensed presentation of the methods and data contained in the paper, "Biochemical Oxidation of Dairy Wastes. I. Methods of Study," published in This Journal, **22**, 3, 318 (Mar., 1950).

Treatment of Dairy Waste by Aeration. II. Continuous Aeration Studies. By Sam R. Hoover and Nandor Porges. Pp. 137-144.

This paper reports the results of studies on a continuous aerobic digestion of a simulated dairy waste by using methods described in the previous paper of this series. The experiments were carried out with controlled temperature, aeration and flow, the influent being added continuously at a fixed rate and the effluent sampled daily. A complete solids balance was established.

The apparatus and methods used for carrying out the continuous flow experiment are described and the data collected are shown in the paper. The results of the aerobic assimilation of the simulated milk wastes are shown in a so-called solids balance sheet. Of 100 parts of dry solids in the waste containing 35 parts of protein

and 53 parts of carbohydrates, 34 parts of the protein were assimilated into cell substance while only 7 parts of carbohydrates were assimilated. Forty-four (44) parts of the carbohydrates were destroyed in oxidation to provide energy for the growth of the cells.

It is pointed out that if the higher oxygen requirements which accompany the high rate of assimilation of dairy wastes by microorganisms can be met, dairy wastes and related strong organic wastes might be satisfactorily treated in conventional biological treatment systems. If aerobic conditions are maintained, by-products of oxidation are negligible and acids do not accumulate. Somewhat greater quantities of sludge produced would have to be handled but this could be done in a conventional manner. A suggested treatment plant flow diagram for the aerobic assimilation of dairy wastes is shown.

D. A. Okun

Anaerobic Treatment of Food Canning Wastes. By R. A. Canham. Pp. 145-158.

The process and results of more than six weeks' full-scale treatment of tomato and lima bean canning wastes by digestion and lagoons are reported. Wastes are screened, digested 2.5 days in an open pond, and discharged through four holding lagoons in series. With digester loading averaging 34 lb. of B. O. D. per 1,000 cu. ft., approximately 40 per cent reduction was obtained. Although straight lagooning using nitrate had resulted in objectionable odors the previous year, strong odor was noted only at the digester a few days and little was noted at the lagoons. Flow and analyses were determined daily and are presented in tables and graphs.

Designing a Distillery Waste-Disposal Plant. By Alex B. Davidson. Pp. 159-167.

Stream requirements dictated that the dryhouse recovery system effluent have a B. O. D. not in excess of 50 p. p. m. during the summer. Better than 98 per cent of the polluting material is removed in the dryhouse and treatment for the effluent was designed to remove about 93 per cent of that remaining.

Four wastes are included: evaporator condensate, cooling tower overflow, doubler tailings, and washings. These total 85,000 g. p. d., with an estimated B. O. D. of 700 p. p. m. The production of each waste and its known or estimated concentrations are discussed.

The treatment plant consists of a primary clarifier, high-rate trickling filter, secondary clarifier, digester, and sludge drying beds. The filter was designed for a load of 0.75 lb. B. O. D. per cu. yd. (1,210 lb. per acre-foot) and a recirculation ratio of 4 to 1, which was found from previous experience to be satisfactory. The design and loading factors of all units are discussed and a plant layout is given. The plant had recently been completed and no operating results were available.

Design and Loading Factors for Anaerobic Fermentation Plants. By Arthur M. Buswell. Pp. 168-174.

The writer explains differences in results achieved through aerobic and anaerobic treatment, devoting particular attention to the advantages and limitations of anaerobic fermentation. He quotes the design data for one large plant handling yeast wastes, and in a table and remarks, summarizes performance data for digestion at four industrial waste plants and one pilot plant. In three plants it is interesting to note that B. O. D. reductions of 70 to 80 per cent were obtained at digester loadings slightly above 0.1 lb. per cu.ft. per day.

Commercial Solvents Corporation Waste-Disposal Plan, Peoria, Illinois, Plant. By M. Wheeler. Pp. 175-180.

This paper reviews the research and decisions at a large fermentation plant where studies were made on sedimentation, chemical treatment, biological oxidation, and anaerobic digestion, and describes the development of the process and equipment used to evaporate, dry, and market waste beer slop as high-vitamin animal feed. A new unit consisting of a quadruple-effect evaporating unit and spray dryers was completed in 1949.

Yeast Growing on Brewery Waste. By P. W. Lin. Pp. 181-190.

The analyses and characteristics of spent-grain press liquor are given and discussed in accordance with its suitability for growing yeasts and thereby reducing the polluting value. Experiments made in 2,500-ml. glass bottles, using a number of

yeast strains under controlled conditions, showed that in four days incubation time the 5-day B. O. D. and total dissolved contents were reduced 55 and 84 per cent, respectively. Further reduction could be expected by settling out the suspended solids and using that material as a stock food.

WM. A. HASFURTHER

Laboratory Experiments on the Behavior of Gravity Separators. By G. A. ROHLICH AND A. C. INGERSOLL. Pp. 203-214.

The hydraulic characteristics of settling tanks as they may result from the studies of dispersion curves are discussed. The behavior of a specific flow through a tank of particular geometry is indicated by plotting the concentrations of an added tracer against the time of effluent sampling in minutes. A comparison of different dispersion curves can be made by reducing them to dimensionless form which, as described, can be done without affecting hydraulic characteristics.

By use of dispersion technique, experimentation was initiated at the hydraulic laboratory of the University of Wisconsin in 1948, sponsored by the Committee on Refinery Waste Disposal of the American Petroleum Institute. A lucite tank 10 ft. long by 5 ft. wide by 3 ft. deep with suitable approach channel, waste channel, weighing tanks, flow meters, and other appurtenances was used.

Potassium permanganate dye, sodium chloride, and sodium phosphate were used as tracers in the tests. The dye gave the best visual indication of stagnant zones and of worst short circuiting, but did not yield acceptable quantitative information. Sodium chloride did not behave like water. Sodium phosphate furnished the best technique, in which a dose of 700 mg. produced a clear dispersion curve with values of concentrations determined by spectrophotometer, within acceptable limits of accuracy. About 60 samples were collected per run, time extending to three or four times the detention period.

Comparative observations have thus far been made on a tank equipped with an influent weir followed by a simple vertical baffle 4 in. deep placed 6 in. downstream from the weir, and on one in which a horizontal slotted baffle similarly placed with respect to influent weir replaced the simple vertical baffle. The slots were $\frac{1}{4}$-in. wide spaced at $1\frac{1}{2}$ in. over a 2-ft. depth. Results to date indicate that (1) dispersion curve studies present a means of determining hydraulic behavior of gravity separators and that the technique is a valuable tool in comparing and evaluating different types of tanks; (2) an overflow weir and simple vertical baffle influent configuration produces severe mixing and short circuiting; and (3) replacing the simple vertical baffle by a slotted horizontal baffle improves velocity distribution and results in greatly improved hydraulic characteristics. The above initial conclusions have been substantiated by motion pictures of the movement of wax particles (0.02-cm. diameter) introduced at the influent. In contrast to the retention efficiency of a separator, which varies inversely with the flow rate, it has been found that the hydraulic characteristics are primarily functions of tank configuration and show little variation with flow rate.

BRUCE M. MCDILL

Biological Indices of Stream Quality. By WILLIS M. VAN HORN. Pp. 215-222.

The science of biology is useful in the evaluation of stream ecology in pollution in two ways: first in field studies, and second in laboratory work.

Pollution causes variation in stream populations because it causes environmental changes. These changes, in turn, may enable some species to become dominant to the point that they destroy the others. There is a brief account of the types of forms generally found in the various "zones" of pollution. It is concluded, however, that it is dangerous to rely too much upon generalizations, and that the population balance in each stream must be studied and carefully established before the biological method is entirely reliable.

There is a discussion of the use of toxicity tests in determining the effect of industrial wastes on stream inhabitants. The author describes his experience in the use of such tests in relation to kraft pulp mills. It is pointed out that, if toxic components are identified, and their source determined, such information is useful in altering established mills or designing new ones to avoid possible trouble.

The advantages and disadvantages of the use of biological methods are discussed.

W. M. VAN HORN

Treatment of Acid, Cyanide, and Chromium Wastes. By C. F. WAITE. Pp. 223-231.

Complete reduction of toxic materials is needed because discharge is to a source of water supply. Cyanide in concentrations of 12 to 20 p. p. m. as KCN are treated in an alkaline solution by oxidation with gaseous chlorine. Chromium and nickel wastes are combined, the pH adjusted to 4.5 or less, and the hexavalent chromium reduced to trivalent with SO_2. This was found to be more economical than treatment with ferrous sulfate.

Diagrams are given showing the arrangement of tanks, feeding equipment, lagoons, and an overflow device, and each operation is described. The plant was designed so that no waste can discharge without treatment, and controls have been devised. Effluent from the toxic material treating plant combines with acid, alkaline, and soap-carrying wastes for discharge to parallel lagoons. These are arranged so that in case of breaks, lagoon capacities can be increased and the contents treated by recirculation through the treating plant. Treatment of 200,000 g. p. d. of waste solution costs about $14 in material and one man-day in labor.

Peculiar Characteristics of Chromium. By DON E. BLOODGOOD AND AUBREY STRICKLAND. Pp. 232-242.

Incomplete removal of chromium compounds in ion exchange units and rapid deterioration of exchange resins prompted an extensive study of the chemistry of chromium. This paper explains the unusual valence characteristics, the hydrolysis, the formation of multinucleate complexes by hydroxyl bridges (olation), and the oxolation of chromium salts.

This study shows that removal of chromic cations from solutions by ion exchange resins involves more than simple ion exchange. To overcome difficulties, tests were made and described using a quaternary amine type of resin and hydrogen peroxide as a reducing agent. This showed some improvement and newer resins are to be studied.

Wm. A. HASFURTHER

Disposal of Oil-Field Salt Waters. By W. S. MORRIS. Pp. 243-251.

The disposal of large volumes of salt water from oil wells is a serious problem because of the effects of the salt on fresh-water supplies for domestic and livestock purposes and on fish life in fresh-water streams.

The paper describes methods by which the brines from the East Texas oil fields are returned to the original salt-water reservoirs below the oil-bearing sections, thus eliminating the disposal problem and at the same time maintaining the bottom hole pressures and supplying the energy for lifting the remaining oil to the surface. Furthermore, it is estimated that, as a direct result of the $4,400,000 invested in salt-water disposal facilities, more than 600,000,000 barrels of additional oil will be recovered from the East Texas fields.

A Pilot Plant for Lime Neutralization Studies. By WALLACE E. WING. Pp. 252–260.

This paper reports findings obtained with a pilot plant built to study the application of lime for the neutralization of acid waste pickle liquor.

By adding dry quicklime directly to the acid waste in a reactor, using slightly less than 10 per cent excess over the stoichiometric requirements, it was found that 200 gal. of waste could be neutralized in from 2 to 3 hr. The dissolved salts were precipitated satisfactorily, and the solids could be dewatered on a rotary vacuum filter.

When a lime slurry was used, a satisfactory reaction was obtained by adding the acid waste to the slurry. The solids filtered well, yielding a cake of 58 per cent moisture, dry enough to be handled easily. The filtrate was clear. The total volume of waste to be handled was reduced by using the filtrate to slake the lime required for neutralization. The effects of various ratios of filtrate and water are shown.

It is also shown that treating hot acid wastes is preferable to treating cold acid because of increased rate of filtering and lower moisture content of the cake.

Conservation on an International Basis. By Howard H. Michaud. Pp. 261–267.

This paper discusses the problems of conservation of natural resources over the world, as presented at the United Nations Scientific Conference on the Conservation and Utilization of Resources, held at Lake Success in August, 1949.

Several examples of conservation problems in different areas of the world are enumerated, with particular emphasis on agriculture.

The author points out that community growth and standard of living are closely tied to the development, utilization, and conservation of natural resources.

Conservation of Water Resources. By Sheppard T. Powell and A. Chesley Wilson. Pp. 268–285.

This paper discusses the water resources of the United States and cites examples of areas where these resources are limited and are being overdrawn.

About half the people in the United States, millions of animals, millions of tilled acres, and thousands of industrial plants depend upon ground waters. The exhaustion of underground waters by concentrations of industries has threatened the future development of many sections of the country. Underground water levels have dropped and in coastal areas salt water has invaded the fresh-water aquifers. In certain areas some relief has been obtained by using surface waters during periods of the year when they are available, permitting natural recharge of the aquifers, and conserving the cool well waters for summer use. More important to the conservation of underground supplies has been the artificial replenishment of ground waters by introducing used water to underground reservoirs through recharge wells and through recharge basins. Many states have laws controlling the withdrawals of ground water in critical areas.

The paper contains only a brief reference to the surface water resources of the United States. A method for utilizing the river waters in the Texas gulf coast area is described. Because of the great variability in river water quality from season to season, off-channel reservoirs were constructed to store the wet-weather runoff for use during dry periods when the river water is high in dissolved minerals and the flows are low.

Projects utilizing treated sewage for industrial water supplies are now in operation and others are being studied. The Bethlehem Steel Company uses about 50 m.g.d. of effluent from the Baltimore, Md., activated sludge and trickling filter plant. A comprehensive program for the re-use of sewage and industrial wastes in Los Angeles County, Calif., has been proposed.

A discussion of water conservation in industry by the recirculation of water through cooling towers and by the recirculation of waste wash water is included in the paper.

Disposal of Waste Pickling Liquids. By Thomas F. Reed. Pp. 286–295.

A satisfactory method for disposal of waste pickling liquor from the steel industry has not yet been developed. The magnitude of the problem is evidenced by the fact that 500,000 tons of sulfuric acid are used for pickling annually, with the production of more than 600 m.g. of waste liquor. If all this acid were recovered as copperas, more than 1,000,000 tons of copperas would be produced, or more than 20 times as much as has ever been sold in a year. The same situation holds with respect to other possible recovery products. Consequently, there is no process in sight which offers any promise of the disposal of such large quantities of waste liquor except at a net cost to industry, or perhaps a very modest profit in special instances. The two processes presently used for the disposal of large quantities of acid wastes include the production of copperas for such markets as do exist and neutralization of the acid with lime.

Other processes that are discussed in the paper include those yielding electrolytic iron, sulfuric acid, ferric sulfate, or ammonium sulfate. The difficulties with these processes are economic.

The author concludes that the possibility of developing new and profitable methods of disposing of waste pickle liquors is slight because intrinsically the value of the material in the waste is low even in its original state. The suggestion

is made that studies should take the direction of looking for processes to reduce the amount of acid required for pickling, or perhaps even eliminating the use of acid for pickling altogether.

D. A. OKUN

Organic Constituents of Strawboard Waste. BY N. J. LARDIERI. Pp. 296–304.

The rotary liquor waste from the manufacturing of strawboard was selected for study. Characteristics of the liquor used are as follows: Total solids, 79,000 p.p.m.; total volatile solids, 61,200 p.p.m.; percentage of volatile solids, 77.4; 5-day B.O.D., 32,000 p.p.m.; and pH, 8.2.

Pentasanic compounds comprise 18 per cent and lignin 10.1 per cent of the dry rotary liquor solids. It was found that reducing sugars were not present in the waste. Preliminary B.O.D. tests show that the biological breakdown of lignin proceeds at a slow rate. Molds grow well in the rotary waste liquor, suggesting the production of riboflavin by the mold *Ermothecium ashbyii*. This is being investigated.

Factors Involved in the Drainage of White Water Sludge. BY J. F. VOGLER AND W. RUDOLFS. Pp. 305–315.

Laboratory studies of drainability properties of white water sludge indicate that (a) it drains somewhat faster than digested sewage sludge; (b) the lower the solids concentration, the more rapid and complete is the drainage and the drier the sludge cake; (c) depth of sludge application is not a factor unless rapid drainage is desired; and (d) in general, chemical conditioning with coagulants has little, if any, beneficial effect on drainage.

Sludge cake, with a B.t.u. value of 7,000 per pound, will support combustion for moisture contents of 85 per cent or less.

Design of a De-inking Waste-Treatment Plant. BY A. J. PALLADINO. Pp. 316–329.

Design details are given for a full-scale, demonstration, de-inking waste treatment plant proposed for the Michigan Paper Company in Plainwell, Mich. The plant consists of a primary settling tank, aeration tank, secondary settling tank, secondary sludge concentration tank, and primary and secondary sludge lagoons. Primary units are designed to handle a flow of 0.5 m.g.d., secondary units 0.167 to 0.25 m.g.d. The primary tank provides 2-hr. detention; the aeration tank, 8-hr.; the secondary settling tanks, 2-hr.; sludge concentrating tank, 15-hr.; and primary and secondary sludge lagoons, each 90 days. Based on pilot plant results it is expected to remove 60 per cent of suspended solids (1,050 p.p.m. remaining in plant effluent) and 68 per cent of B.O.D. (200 p.p.m. remaining).

Pollution-Capacity Studies of the Wabash River. BY R. K. HORTON. Pp. 330–337.

This stream survey was featured by intensive sampling over a short period of time to provide the proper data for later statistical analysis and the application of theories of probability so that a series of variables could be projected to a knowledge of conditions in the river under varying circumstances of flow, pollution loading, and river quality. Field data on pollutional loads contributed was secured. Analyses on river samples included temperature, dissolved oxygen, B.O.D., pH, total and volatile suspended solids, alkalinity, nitrates, and most probable number. River cross-sections were taken and sludge deposits located and measured. Runoff records were available. This survey was conducted by or participated in by nine private and public agencies. Final analyses and interpretations were not available when the original paper was presented.

K. W. COSENS

Pulp and Paper Mill Wastes. BY F. V. DOUTT. Pp. 338–344.

This general discussion of the waste problems in the pulp and paper industry outlines several of the corrective measures now in operation and/or contemplated as a result of laboratory and pilot plant study. A plea is made for formulation of a more precise definition of the degree of correction necessary for the best interests of all concerned with water resource usage, to the end that industry will have a stated goal toward which to guide its efforts.

The Determination of Phenolic Materials in Industrial Wastes. BY M. B. ETTINGER AND R. C. KRONER. Pp. 345–359.

Preliminary screening procedures for elimination of substances interfering with the phenol determination are discussed, as well as the use of bromine demand as a measuring technique for the estimation of phenol. Interpretation of phenol tests, either by bromination or by the various modifications of the Gibbs procedure is considered at length, the reported amounts corresponding to the minimum phenol present. Advantages and disadvantages of 4-aminoantipyrine as a test reagent for phenols are considered. Two appendices give in detail a tentative procedure for the determination of phenol in by-product coke wastes and the method of phenol determination adopted by the Board of Technical Advisers of the International Joint Commission.

The Foundation of Successful Industrial Waste Disposal to Municipal Sewage Works. By W. H. Wisely. Pp. 360–365.

The salient points of this paper are contained in an excerpt published in This Journal, 22, 1, 93 (Jan., 1950).

The Position of the Pebble Phosphate Industry of Florida in Stream Sanitation. By R. B. Fuller. Pp. 366–371.

An abstract of a discussion by this author on the same subject appeared in This Journal, 21, 5, 944 (Sept., 1949).

Developments in Industrial Waste Treatment in Iowa. By Philip F. Morgan. Pp. 372–378.

This is a general discussion of the new Iowa pollution law and a review of the developments of 1948 and 1949 in industrial wastes treatment plant construction and operation in Iowa. Discharge of unsaleable technical chlordane (in the form of grasshopper poison) to a city sewer was responsible for an extensive fish kill at Waterloo, Iowa. Evidence points to chlordane concentrations as high as 4 p.p.m., with 0.5 p.p.m. being toxic to the species of fish affected.

A Proposed Biological Measure of Stream Conditions. By Ruth Patrick. Pp. 379–399.

This paper was published in This Journal, 22, 7, 926 (July, 1950).

H. P. Orland

The Removal of Fatty Acids and Soaps from Soap-Manufacturing Waste Waters. By F. S. Gibbs. Pp. 400–406.

This is a story of pilot plant studies and subsequent design of a full-scale plant to remove oils, fats, and greases from wastes. The plant, which has a short detention and utilizes finely dispersed air and chemicals, was exceptionally successful, but is not described in detail nor are the results of operations included.

Wm. A. Hasfurther

The Dairy Industry Committee Exhibit on Waste Saving. By W. B. Campbell. Pp. 407–410.

The essentials of dairy waste control are presented in outline form. Major emphasis is placed on waste prevention by proper design, maintenance, and operation of equipment.

Milk Wastes in Sewage Sludge Digestion Tanks. By David Backmeyer. Pp. 411–417.

This paper describes the operation of sewage sludge digesters at Marion, Ind., during a period when considerable quantities of whey were disposed of directly to the digesters. The Marion plant has two identical digestion tanks, equipped with floating covers and gas collection equipment; 70,000 cu. ft. capacity per tank (5.2 cu. ft. per capita). The normal load to the digesters consists of primary sewage sludge mixed with waste activated sludge plus the city's garbage, which is ground at the plant and added directly to the digestion tanks.

Introduction of the whey, which contains about 5.5 per cent total solids and has an average B.O.D. of 35,000 p.p.m., always resulted in a surge in gas production. The whey added during the summer months amounted to as much as 18 per cent of the total load added to the digesters. The gas produced was always suitable for use as a fuel in the gas engines and in the plant heating boiler.

In one instance the sewage treatment plant handled a dump load of 11,000 gal. of condensed milk by preventing its discharge directly into the sewers and introducing the milk to the digesters. The milk was utilized in about five days, the digestion of the milk solids being

accompanied by a great surge of gas production. The carbon dioxide content of the gas was not higher than normal. Had the milk been permitted to be discharged into the sewer system, it is likely that the activated sludge process would have been seriously upset.

Progress on Waste Prevention. By George W. Putnam. Pp. 418–420.

The waste control activities of the Task Committee on Dairy Waste Disposal, Dairy Industry Committee, are described. In addition to a substantial educational program in the dairy industry, the Task Committee sponsored a comprehensive study on milk wastes treatment at Michigan State College. A research project was also established with Dairy Industry funds at Purdue University and the Committee is cooperating in the study on dairy waste treatment at the Eastern Regional Laboratory of the United States Department of Agriculture. The Committee is also attempting to coordinate all research in the United States in this field.

Methods of Instigating Research in Dairy Waste Under the Research and Marketing Act. By E. W. Gaumnitz. Pp. 421–423.

This paper reviews the provisions of the Research and Marketing Act of 1946 and discusses in some detail those sections which are applicable to promotion of a research program in the treatment of dairy wastes. The principal channels for the expenditure of funds for dairy wastes research are through allocations to state experiment stations and directly through federal agencies, the Department of Agriculture in particular.

Aeration of Milk Wastes. By William A. Hasfurther and C. W. Klassen. Pp. 424–430.

Experiences with aeration of milk plant wastes from the Huntley, Ill., plant of the Dean Milk Company are described in this paper. The plant receives milk in cans and tank trucks, and stores, pasteurizes, and bottles this in paper containers. Daily production during the period of the investigation reported ranged from 104,600 to 155,460 lb.

All wastes other than drip and prerinse at the can washer, some drip at the bottling machine, boiler waters, and cooling waters discharge to the treatment plant. Milk losses were computed at about 0.8 per cent of the raw milk.

The aeration tank (20.5 ft. by 11 ft. by 8 ft. deep) has a capacity of 1,804 cu. ft. and is equipped with 14 impingement aerator jets of 6-c.f.m. capacity each. The first aeration installation was found to be too small and unsatisfactory in operation. The recirculating pump also had to be increased in capacity to provide 2 gal. per cubic foot of air. The ratio of raw to recirculated flow was about 1 to 5. Sludge from the settling tank following the aeration tank is returned to the aeration tank by air lift. No facilities are provided for disposing of waste sludge, although it was found necessary to waste solids fairly often.

Data are shown of test results during a preliminary period when the aeration was unsatisfactory and insufficient oxygen was present in the aeration tank. Improving the aerators and increasing the aeration capacity yielded satisfactory results, except when the mixed liquor solids in the aeration tank exceeded about 3,500 p.p.m. Aeration tank detention periods ranged from 16 to 23 hr., with detention in the final tank of 1.5 to 6 hr. The quality of the effluent depended on the character of the sludge, rather than on the detention period. It is concluded that with careful control of the sludge in the aeration tank a B.O.D. loading of 1 lb. per 1,000 cu. ft. of air and 1 lb. per 30 cu. ft. of aeration tank capacity can produce good results.

D. A. Okun

Proceedings, Twenty-Third Annual Conference, The Maryland-Delaware Water and Sewerage Association (Apr., 1950).

Articles of particular interest to the sewage works field include the following:

The Birth Pains of the LaVale Sanitary District. By W. A. Douglas.

The establishment of a sanitary district mainly for water supply purposes for LaVale, a suburb of Cumberland, Md., presented many problems, which are reviewed. Those interested in the formation of a similar district might find this a very interesting article.

Sewage Treatment for Cumberland, Maryland. By Ralph L. Rizer and Gustav J. Requardt.

Cumberland, Md., situated on the Potomac River, discharges all sanitary sewage directly into the river without treatment, causing severe river pollution within and below the city. A study of the river and sewage flows was made and it was decided that primary treatment would be provided. A very interesting chart illustrating the ability of the river to handle B.O.D. loading is given. A combination of general obligation bonds and revenue bonds were favored as the method of financing.

The Origin, Operation and Improvements to the Municipal Disposal Plant at Frederick. By R. H. Hartman.

This paper was published in This Journal, **23**, 1, 98 (Jan., 1951).

Baltimore's Design of Small Sewers. By B. F. Suwall.

Sewer extensions or improvements follow a definite pattern; the subdivider must secure permission, then finance and install sewers under city inspection and specifications. Design of the sewers is done by the city engineering staff. Design specifications are summarized and conform to general practice in most respects.

Pollution Studies of Baltimore Harbor. By C. F. Garland

Different phases of the sanitary engineering study of the ability of Baltimore harbor to accept discharge of wastes are thoroughly discussed. The project involved a study of prevailing wind direction and velocities; land-water flow into the harbor, including sewage and industrial wastes; water sampling at 13 stations and at several depths for each station, to be used for analysis; water analyses for D.O., B.O.D., temperature, pH, chloride ion concentration, and bacteria.

Water and Sewerage for Consolidated Schools. By J. R. McComas.

Recommended methods of solving water supply and particularly sewage disposal problems at public schools where public sewers are not available are discussed. Sewage flow rates are given at 50 g.p.c.d. Although only 25 g.p.c.d. will be contributed, the flow occurs over an 8-hr. period. Details for determining soil percolation capacity and design criteria are given for both cesspool and tile field methods of disposal.

K. W. Cosens

Basic Water Use Doctrines and State Water Control Agencies. A Committee Report. *Jour.*, Amer. Water Wks. Assn., **42**, 755 (Aug., 1950).

In order to obtain this information a temporary committee on the subject was appointed by the American Water Works Association. The actual work was aided considerably by the fact that several members of the committee were currently engaged on a nation-wide water resources investigation, which made it necessary to obtain similar data for more than half of the 48 states. Due to the broad field covered by water control law, the committee has limited itself to presenting a summary of the basic use doctrines and to noting for each state what agencies perform the several functions pertaining to water resources control.

Basic water laws for surface waters are covered by the riparian doctrine (which derives from the common law) and the appropriation doctrine (generally provided for by statute). In turn, ground water is covered by (1) the English or common law rule of absolute ownership by the owner of the overlying land, (2) the American Rule of reasonable use, and (3) the doctrine of appropriation as adopted from the principles for surface waters. It is significant to note that the riparian and common law doctrines are generally followed in the eastern part of the United States, whereas the appropriation doctrine is used almost exclusively in the western states.

In addition to the basic law for surface and ground waters a summary table includes each state water control authority or agency for (1) surface water, (2) ground water, (3) dams, diversion works, etc., (4) water quality and treatment—public supplies, (5) water quality and treatment—industrial water, (6) stream pollution control, (7) sewage disposal—technical, and (8) industrial waste disposal—technical. There is also a table that gives the various interstate compacts and agreements, with the participating states.

Statistical information shows that 29 states, including all of the 17 western

states, have agencies that exercise some control over the use of surface water. There are 26 states that have some agency with authority over ground-water use. All of the states have statutes forbiding nuisances or actions affecting the public health. Of the 48 states, 43 have definite laws for controlling stream pollution, and in about one-half the states the state health department has control, except for fish and game.

In conclusion it is stated that the legal aspects of water resources control are becoming more and more important. The significance has been recognized in the western states for a great many years, but only comparatively recently has public appreciation of the water supply problem become pronounced elsewhere.

ROBERT P. LOWE

Living with the Atom. BY NORMAN R. BEERS. *Jour.*, Amer. Water Wks. Assn., 42, 729 (Aug., 1950).

This paper by the late editor of *Nucleonics* gives a broad picture of the future atomic age by one who is well qualified to look ahead on this subject. Emphasis is placed on adjustment to the age and on the benefits that can be derived, in contrast to the conventional thinking in terms of atomic bombing.

The ability of the older person to continue to learn and the importance of applying this ability to the rapidly-changing field of atomic energy is stressed. Sources of reading material for the literate citizen are recommended, and among these are *Nucleonics* and the semiannual reports of the Atomic Energy Commission. The need for a daring attitude by scientists and others in this field of work is emphasized as a prerequisite for speed in development of possibilities.

The use of atomic energy as a source of heat energy for the desalting of sea water is brought out as a likely possibility for the solution of many water needs in an economical manner. Atmospheric pollution by radioisotopes and the relation of air pollution to rainfall are discussed in view of the control that may revolutionize these fields.

ROBERT P. LOWE

Magnitude of Industrial Demand for Process Water. BY SHEPPARD T. POWELL AND HILARY E. BACON. *Jour.*, Amer. Water Wks. Assn., 42, 777 (Aug., 1950).

A very comprehensive picture of the magnitude of the industrial demand for water is given in this paper, and its significance to the over-all national water resources and pollution control problems is brought out.

Numerous descriptions of large water using industries are made, and it is pointed out that many of them recirculate most of the supply. It is also shown that the quantity of water required for each dollar of "value added by manufacture" varies widely. For high users of water for each dollar of added value, the costs of supply and treatment are of predominant importance and will play a definite part in location of such industries. Various tables indicate the tremendous differences in water demand in the industrial classifications that are available.

The basic conditions for the failure of water supplies to meet community requirements are given as follows:

1. Failure to provide for equalization of surface-water runoff.
2. Overconcentration of population and industries.
3. Withdrawal of water from underground aquifers in excess of natural recharge.
4. Water wastage.
5. Failure to use available salt water in place of fresh water.
6. Selection of plant sites without adequate evaluation of availability of water for existing or predictable future requirements.
7. Inadequate design and planning of water-consuming processing equipment.

Corrective measures are indicated by the points in the following program:

1. An inventory of individual water requirements on a national basis coordinated with actual and potential surface and ground-water resources available (this survey should be both local and regional, conforming to major river basins and geological formations).
2. Discouragement of overindustrialization within critical, or potentially critical, watersheds.

3. Decentralization of industrial users of large volumes of water.

4. Inter- and intrastate control and regulation of flood waters to provide present and future industrial water requirements, regardless of other benefits accruing from such facilities.

5. Encouragement of salt-water usage as a conservation measure.

6. Expansion of the activities of the state and federal agencies handling critical underground-water resources.

7. An increase in the number of technical personnel of the U. S. Geological Survey and provision of the necessary funds to effect more adequate utilization of the valuable services of this organization.

8. Coordination of the activity of waste disposal regulation groups with allocation of water resources.

A program of this sort will require much more cooperation and long-term planning than is currently practiced, and existing data must be digested and additional information will need to be obtained in order to properly evaluate the problem and control it.

ROBERT P. LOWE

Possible Hazards from Chemical Contamination in Water Supplies. BY C. W. MUEHLBERGER. *Jour.*, Amer. Water Wks. Assn., **42**, 1027 (Nov., 1950).

The toxic limits of various harmful chemical impurities of water supplies are discussed in this paper, particular attention being paid to those created by industrial wastes. It is brought out that there is considerable information on a single toxic dose, but continuous exposure to small amounts through the water supply produces a different situation that indicates a need for more factual knowledge. The matter is complicated by the differences in the ability of the human body to rid itself of the various chemicals and also by the variability of individuals in what constitutes a toxic level.

Limits for toxic chemicals have been set below the toxic level for some substances where adequate data has been obtained. Examples are lead at 0.1 p.p.m., fluorine at 1.5 p.p.m., and arsenic at 0.05 p.p.m., that may be present on fruits or vegetables as a result of spraying operations. As copper and zinc are easier to eliminate (in contrast to accumulation) from the body than lead and arsenic, their safe concentrations are set higher. It is stated that the hazard is not great from selenium and cyanides, but that more study is needed on them.

Of the other toxic substances that may conceivably be found in drinking water, chromium and cadmium have recently come into consideration, and they are discussed in detail. Both elements are used in industry and emanate from plants in their liquid wastes. The hexavalent form of chromium is decidedly poisonous. It is used extensively in the plating of metals and for corrosion prevention in cooling-water systems. It is concluded that the 0.05-p.p.m. limit on hexavalent chromium in the U. S. Public Health Service standards is amply safe and may be too rigid. Cadmium became prominent during World War II, when it was substituted for zinc and tin for rust-resistant coatings on utensils and containers in contact with foods. A wave of poisonings resulted, but permanent injury was rare. Not enough information on the toxicity level on human subjects is currently available for cadmium.

Discussion. BY RAY L. DERBY.

The necessity of safe standards is pointed out, but the possibility of economic hardship created by retention of such standards indefinitely points to the need of immediate investigations to determine more precise limits. The case of the boron content originally set at 1.0 p.p.m. for citrus grove irrigation and then lowered to 0.5 p.p.m., is cited as an example of change after obtaining additional information. The lack of data on other substances such as lithium, catadyn silver, radioactive materials, and even chlorine, is also pointed out. Research aid on the toxic effects of the heavy elements and other compounds would appear to be justified, according to this discussion.

ROBERT P. LOWE

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Proceedings of Member Associations

KENTUCKY-TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The Fourth Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held at the Peabody Hotel, Memphis, Tenn., October 23–25, 1950, in conjunction with the Kentucky-Tennessee Section, American Water Works Association. Registration for the meeting totaled 225.

After being welcomed by T. H. Allen, president, Memphis Light, Gas and Water Division, on October 23, greetings were extended by A. P. Black, past president, AWWA, and A. H. Niles, president, FSIWA, on behalf of the respective national organizations.

At the joint afternoon session, papers of interest to those in both fields were presented, as follows:

"Pollution Control Activities of the Ohio River Water Sanitation Commission," by E. J. Cleary, executive director and chief engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

"The U. S. Public Health Service Stream Sanitation Program," by W. W. Towne, officer-in-charge, Ohio and Tennessee Drainage Basins, U.S.P.H.S.

"Financing Municipal Utilities," by L. E. Caffall, financial consultant, New York City.

"Services of the U. S. Geological Survey," by W. R. Eaton, district engineer, U.S.G.S., Chattanooga, Tenn.

An evening social hour gave all an opportunity to become acquainted or to greet old friends.

Both the morning and afternoon of October 24 were occupied by concurrent water and sewage sessions. Papers presented at the industrial wastes and sewage sessions included:

"New Developments in Sewage Treatment," by K. V. Hill, Greeley and Hansen, Chicago, Ill.

"Sewage Treatment Plant Operation," by a panel consisting of J. W. McAmis, Greeneville, Tenn.; J. Barro, Tullahoma, Tenn.; G. L. Robinson, Memphis, Tenn.; and L. Birkel, Jr., Louisville, Ky.

"Sewerage System Record Keeping," by K. B. Stallings, Engineering Department, Nashville, Tenn.

"Solving Industrial Waste Problems," by G. M. Oliensis, International Shoe Co., St. Louis, Mo., and J. Heykoop, American Enka Corp., Lowland, Tenn.

"The Relationship of B.O.D. to the Dichromate Oxygen Consumed Value," by L. R. Setter, W. A. Moore, and C. C. Ruchhoft, U.S.P.H.S., Cincinnati, Ohio.

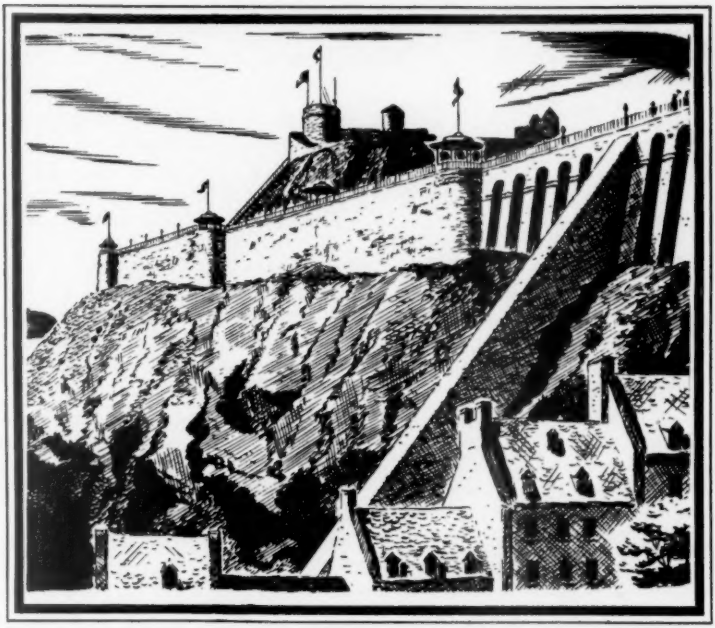
"Research in Industrial Waste Treatment and Recovery," by D. E. Bloodgood, professor of sanitary engineering, Purdue University.

At the Annual Dinner, the entertainment was furnished by the Memphis Fire Department. Dancing rounded out an enjoyable evening.

A joint business session on the morning of October 25 preceded a description of the Memphis water supply, by F. C. Pentecost, Memphis Light, Gas and Water Division, following which an inspection trip was made to the system's Sheahan pumping station. Luncheon furnished by the Division was enjoyed by the visitors on the pumping station grounds.

Officers elected to serve for 1950–51 were:

(*Continued on page 186a*)



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Secretary-Treasurer: R. P. Farrell, Nashville, Tenn.

R. Paul Farrell,
Secretary-Treasurer

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 23rd Annual Meeting of the New York Sewage and Industrial Wastes Association was held at the Statler Hotel, New York City, January 19–20, 1951, with a total registration of 327.

At the Annual Business Meeting, held the morning of January 19, the following officers were elected:

President: J. M. MacCrea, Syracuse.
Vice-President: W. R. Schreiner, Glens Falls.
Treasurer: J. C. Brigham, Albany.
Secretary: R. C. Sweeney, White Plains.

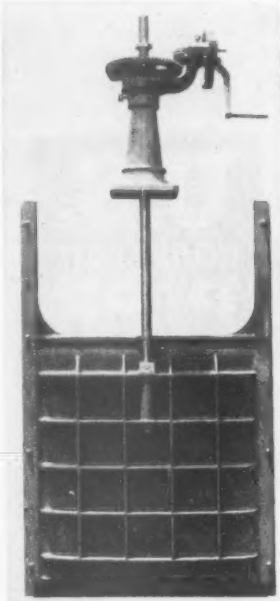
At the morning technical session on January 19 the following papers were presented:

"Relationship Between Sewage and Waste Treatment Works and the Civil Defense Program," by S. T. Barker, Assistant Director, Bureau of Environmental Sanitation, State Department of Health, Albany.

"Pollution Abatement Studies in the North Atlantic Drainage Basin," by Kenneth C. Lauster, U.S.P.H.S., New York City.

At the luncheon meeting, W. H. Wisely, Executive-Secretary, FSIWA, spoke on Federation activities in relation to materials allocations, personnel deferments, and the procurement of chlorine. The Association's Kenneth Allen Memorial Award was presented

(*Continued on page 188a*)



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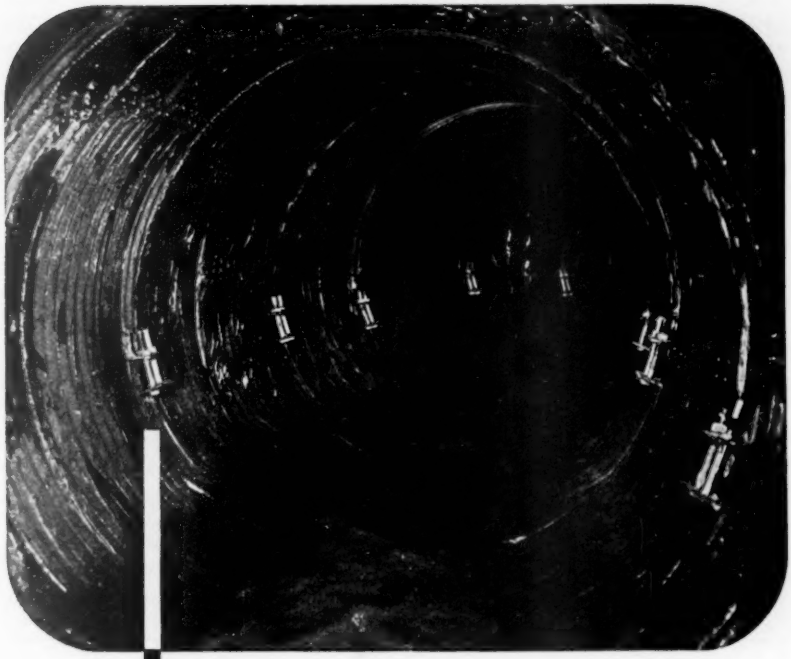

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to S. G. Hess, Director, Interstate Sanitation Commission, New York. Guest speaker at the luncheon was Professor Gordon M. Fair, Harvard University, whose subject was "Let's Look at the Record of Sanitation."

At the afternoon session, a paper on "Effect of Metal Wastes on Sewage Treatment Plant Design" was presented by R. T. Mitchell, J. Cassanos, and D. Okun, Malcolm Pirnie Engineers, New York City. This was followed by a symposium on "Industrial Waste Treatment Problems in New York State," conducted by R. W. Hess, Head, Pollution Research and Operating Improvements, National Analine Division, Allied Chemical and Dye Corp., Buffalo.

A social hour at the close of the technical session was sponsored by the Water and Sewage Works Manufacturers Association.

The morning session on January 20 concluded the meeting with the presentation of the following papers:

"Certification of Sewage and Waste Treatment Plant Operators," by Alexander Rihm, Jr., Assistant Sanitary Engineer, State Department of Health, Albany.

"Preliminary Report on Sewer Rental for New York City," by Richard H. Gould, Director, Division of Sewage Disposal, Department of Public Works, New York City.

"The New Rochelle Sanitary Sewer District in the County of Winchester," by E. H. Feldman, Director, Department of Public Works, New Rochelle.

R. C. SWEENEY,
Secretary

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1950 Annual Meeting of the Florida Sewage and Industrial Wastes Association was held jointly with the Cuba and Florida Sections, AWWA,

(*Continued on page 190a*)

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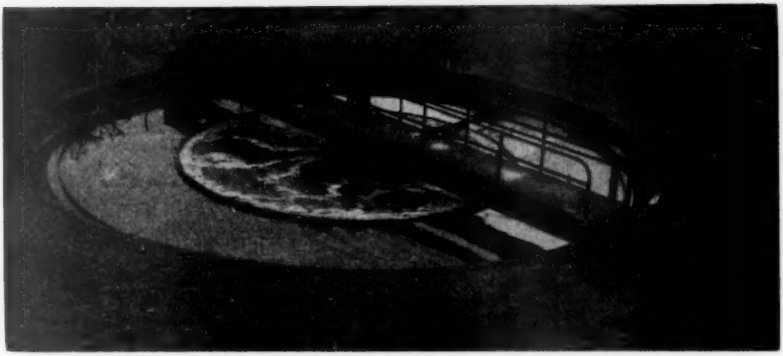

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at the Governors' Club Hotel, Fort Lauderdale, Fla., November 12–15, 1950. Registration for the joint meetings totaled 214, of whom 40 were from the Florida Sewage and Industrial Wastes Association. On the evening of November 12, the City of Fort Lauderdale was host to the group.

The programs for the meeting were joint for the morning sessions and separate for afternoon sessions. At the morning session on November 13 an address of welcome was given by Rev. John H. Hanger, of Fort Lauderdale. Director Ben F. Borden, Jr., followed with a review of Federation activities. A similar review was also given by Secretary Jordan of AWWA. A. P. Black spoke to the session on civil defense matters, after which L. H. Daniel and Manuel J. Fuente gave papers of interest to water works personnel concerning affairs in Cuba.

The noon luncheon on November 13 was a highlight of the meeting. J. Frank Rushton, Jacksonville business man, gave a stirring talk on "The Twilight's Last Gleaming," dealing with atomics and economics.

At the afternoon session for sanitary personnel, John E. Fitzgerald, South Walpole, Mass., presented a paper on "Industrial Wastes." A spirited panel discussion on sewage and industrial wastes followed, led by John W. Wakefield, Florida State Board of Health.

The November 14 morning session was devoted to a paper on "Dilution Disposal of Pulp Mill Wastes in Florida," by Harry W. Gehm, National Council for Stream Improvement. A well-integrated panel discussion of "Water Supply Problems in Florida" was led by A. P. Black, past president of AWWA.

At the sewage and industrial wastes session on November 14 a paper by L. de Goicoechea and L. Radelat of Cuba was presented by L. H. Daniel on "The Cosculluela Process for the Treatment of Distilling Wastes Waters." Following this a paper on "The Sanitary and Storm Sewage Problems of Maranao" was given by J. Montes, Havana.

The joint banquet was held on November 14 at the Bahia Mar Yacht Club. The guest speaker, R. K. Havighorst, Miami, made a short, inspiring address on the depletion of our national resources. Toastmaster for the occasion was the Cuba Section's secretary, L. H. Daniel. The Federation's A. S. Bedell Award was presented to J. R. Hoy.

The new 1950–51 officers of the Florida Sewage and Industrial Wastes Association are as follows:

President: W. J. Parks, Jacksonville.
Vice-President: John E. Kiker, Jr., Gainesville.
Secretary-Treasurer: Perry M. Teeple, Jacksonville.
FSIWA Director: J. R. Hoy, Jacksonville.

PERRY M. TEEPLE,
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Corrugated Metal Pipe—Several new bulletins present data on the types of full-round pipe, arched pipe, and pipe made from multiple plates available to meet the specific requirements for various types of sewers, culverts, conduits, or irrigation systems. Also contained are reference data for assistance in selecting the most suitable structure, as well as details on fittings. Practical instructions on the installation of drainage structures are contained in a special 46-page "Installation Manual."—Armco Drainage & Metal Products, Inc., General Offices, Middletown, Ohio.

Sight Feed Bubbler and Sediment Trap—Two new units for use in gas and air lines are annnounced in Bulletin EX285 describing a sight feed bubbler for controlling and visually indicating relatively small rates of flow and a sediment trap for removing dirt and moisture from the line.—King Engineering Corp., Box 500, Ann Arbor, Mich.

High Capacity Chlorinizer—Bulletin 840–G27 gives installation and operating information on a new high-capacity chlorinizer with feeding rates of from 100 to 6,000 lb. per 24 hr. Of fundamentally the same design as the lower capacity models already in use, the new model is a basic manual unit to which step control, automatic proportioning, and semi-automatic or programmed control may be added without modification of the basic manual unit.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

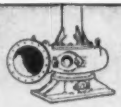
Pipe Expansion Joints—A new 4-page leaflet (Form 5010) describes and gives data for the four principal types (single-end, double-end, single-end with limited movement, and double-end with limited movement) of pipe expansion joints produced by the company. Sizes range from 3-in. inside diameter to 24-in. outside diameter, with larger sizes available on request.—Dresser Manufacturing Division, Dresser Industries, Inc., Bradford, Pa.

Parts Service—Purchase of the plant and equipment of National Transit Pump and Machine Corporation of Oil City, Pa., was recently announced by Worthington Pump and Machinery Corporation, Harrison, N. J. Worthington plans to continue to furnish repair and spare parts for the National Transit products now in the field.

Corrugated Steel Sheeting—Complete engineering data for design and installation of corrugated steel sheeting for trenches, shoring, lagging, cofferdams, or bulkheads are contained in a new 10-page manual (Sh-4650).—Armco Drainage & Metal Products, Inc., General Offices, Middletown, Ohio.

Vacuum Flotation and Grit Removal—Explanations of what the Vacuator is and how it works, together with design data and operating results under various conditions of use, are contained in a new 12-page bulletin (No. 6301).—The Dorr Company, Barry Place, Stamford, Conn.

Clay Pipe Engineering Manual—Engineering reference data applicable to the design and construction of sewer and drainage systems are contained in a 1951 revision of this well-known publication. The 163 pages are filled with specifications, tables, drawings, pictures, and illustrative problems designed to answer all questions concerning clay pipe, liner plate, and filter block usage. Price $3.00.—Clay Products Association, 100 North LaSalle St., Chicago 2, Ill.



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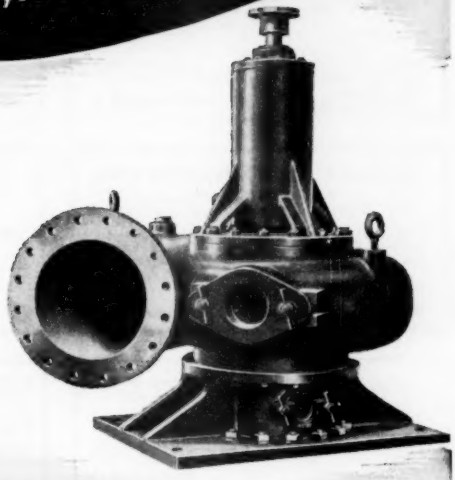

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